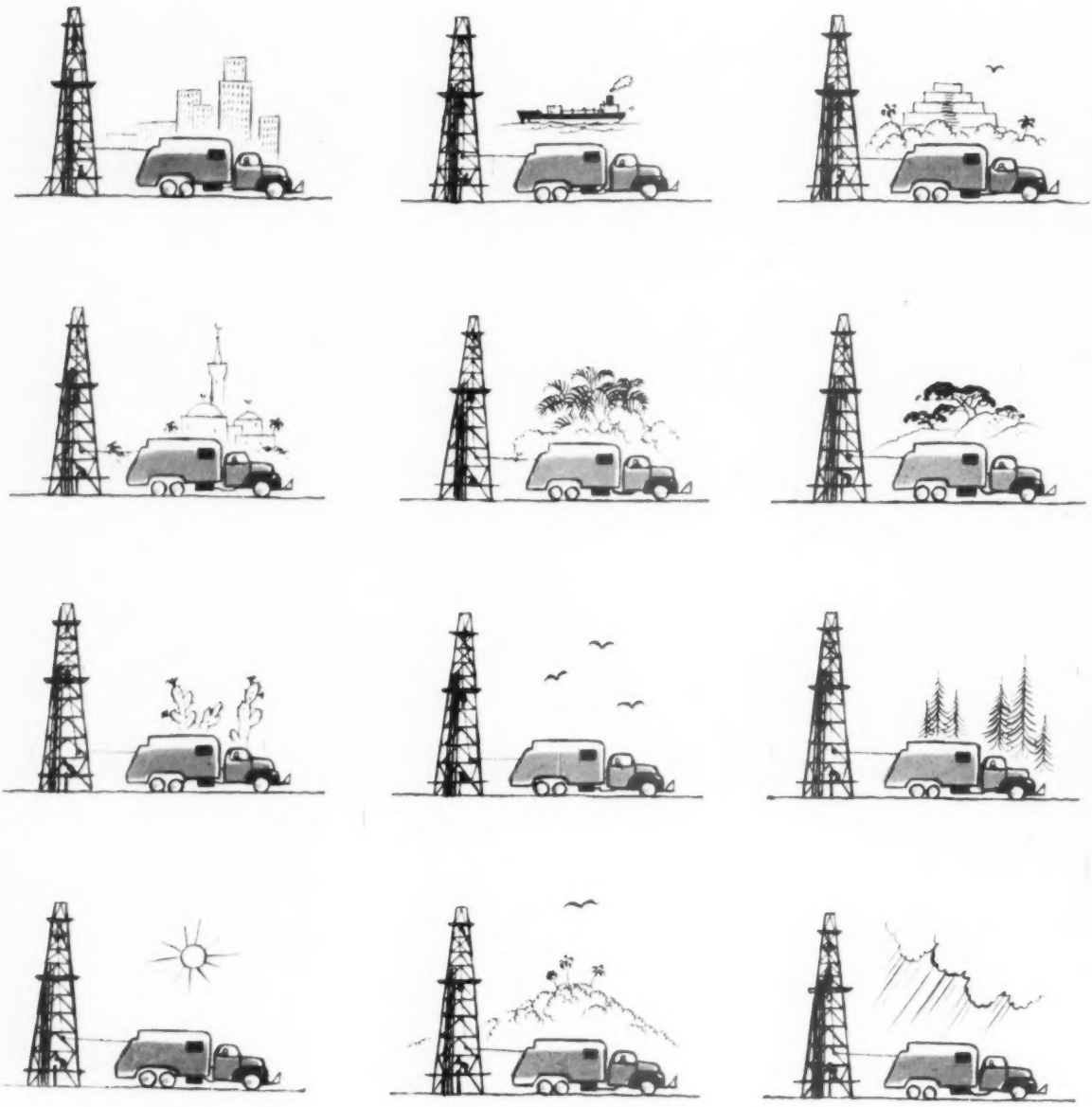
JOURNAL OF Petroleum Technology

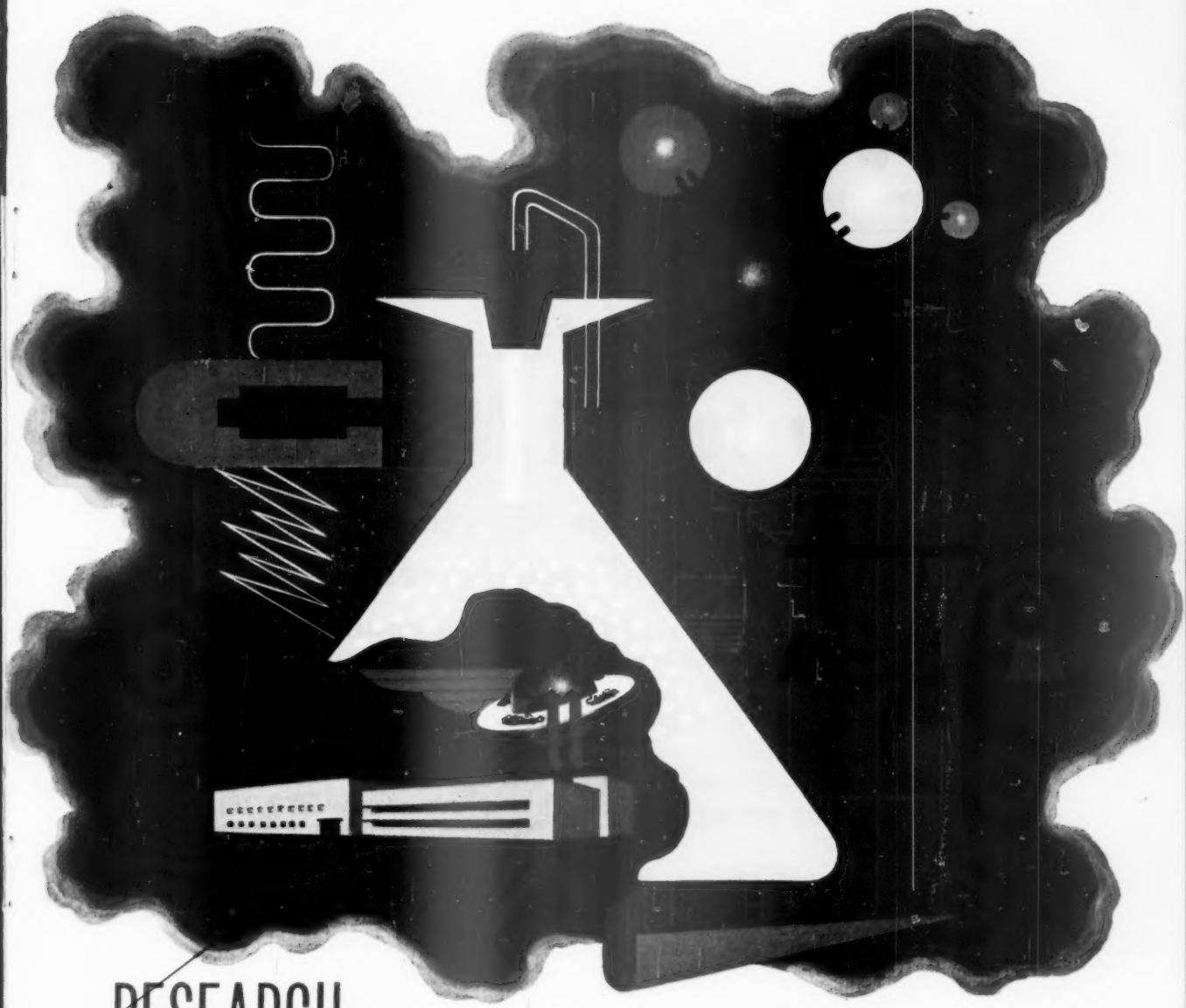
JANUARY, 1953



EVERY LOG A QUALITY PRODUCT!
EXPERT CONTROL IN THE DISTRICT—
EQUIPMENT ENGINEERED FOR THE JOB—
EXPERIENCED ENGINEERS IN THE FIELD

WHY OPERATORS PREFER SCHLUMBERGER!

SCHLUMBERGER WELL SURVEYING CORP. • HOUSTON, TEXAS



RESEARCH ★ THE RESERVOIR OF PROGRESS!

Tomorrow is no secret to the scientist. For much of what tomorrow needs is under test right now. Halliburton works for you that way. Research holds the place of highest concern, and Halliburton's greatest skills are dedicated to developing tomorrow's tools, techniques, and technology.

The challenge of continuous achievement is welcomed by white-jacketed wizards in their chemical, mechanical, and electronic laboratories. They weigh new ideas on the big scale of million-job experience, examine each step in the bright light of 25 years' research, and test again and again by the most rigorous methods known.

Culminating this quarter-century of energetic research is Halliburton's new Technical Center now under construction at Duncan. It will be maintained not only to sustain the high quality of Halliburton's service but to assist you without charge in the solution of a stubborn field problem.

The new Technical Center is a reservoir of production progress for this constantly growing industry. It will reassure you that Halliburton's research will never let up, least of all today.

HALLIBURTON

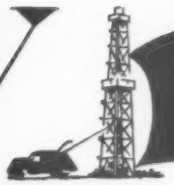
OIL WELL CEMENTING COMPANY

DUNCAN, OKLAHOMA

PERPETUAL PROGRESS IN PRODUCTION IMPROVEMENT TECHNIQUES

What's NEW

In Perforating, Logging, and Fishing Tool Services



McCULLOUGH
NEW SERVICES • NEW TOOLS
NEW WAYS OF DOING THINGS

Latest News About New Tools, Techniques and Services

New Factual Booklet—

"How to Get More Oil"

Read it—then judge for yourself which perforating service will get the results you want

Here's a completely new booklet prepared for production-minded oil men who are interested in getting more oil after perforating.

This new booklet gives you the technical facts on the "hardest shooting perforators in the world" —McCullough Burrless Bullet—McCullough Glass Jet—with particular emphasis placed on the penetrating powers of each type.

This, and other valuable technical information, is yours for the asking. Clip the coupon and mail it TODAY!

HERE'S a partial list of the contents of this New Factual Booklet:

McCULLOUGH PERFORATING SERVICE

- . . . Men behind the guns
- . . . Accuracy through electronics

McCULLOUGH BURRLESS BULLET PERFORATING

- . . . The development of Burrless Bullets
- . . . How the simultaneous firing method gets better results
- . . . How simple, scientific design provides greater power and deeper penetration
- . . . A series of penetration tests covering all sizes of McCullough Burrless Bullet Perforators

McCULLOUGH GLASS JET PERFORATING

- . . . Types and sizes of guns
- . . . Strip Carrier and Solid Bodied Guns
- . . . Advantages of Glass Jet Units
- . . . Recommendations for use
- . . . A series of penetration tests covering all sizes of McCullough Glass Jet Perforators

SUMMARY, RESULTS IN THE FIELD, AND CONCLUSIONS

CLIP AND

Mail Today

McCULLOUGH TOOL COMPANY PT-1
5820 So. Alameda Street
Los Angeles 58, California

Gentlemen:
Please send me my free copy of "How to Get More Oil" by return mail.

NAME_____

COMPANY_____

ADDRESS_____ CITY_____ STATE_____

POSITION_____

JOURNAL OF
Petroleum Technology

EDITORIAL BOARD
PAUL R. TURNBULL
RICHARD W. FRENCH
THOMAS C. FRICK

EDITORIAL DIRECTOR
JOE B. ALFORD

EDITOR
JESS E. ADKINS

MANAGING EDITOR
VIRGINIA BEILHARZ

EDITORIAL ASSISTANTS
BEKY YODER
JOANNE MORAN
LILLIAN ZACHRY

ADVERTISING MANAGER
RICHARD C. WIPPERMAN

EASTERN ADVERTISING SALES
LEWIS V. HOHL
205 E. 42nd St., New York, N. Y.

JOURNAL OF PETROLEUM TECHNOLOGY is published monthly by the Petroleum Branch, American Institute of Mining and Metallurgical Engineers, Inc., at 800 Fidelity Union Bldg., Dallas 1, Tex. Entered as second class matter at the Post Office at Dallas, Tex. Domestic Subscription: North, South and Central America, $8; foreign, $10; to AIME members, $6 (or $4 if in combination with subscription to either Journal of Metals or Mining Engineering). Single copies, 75 cents; special issues, $1.50. Registered cable address, AIME. Printed in USA. Copyright 1953 by American Institute of Mining and Metallurgical Engineers, Inc.

Official Publication of the

PETROLEUM BRANCH
American Institute of Mining and Metallurgical Engineers, Inc.

800 Fidelity Union Bldg.
Dallas, Texas

Statements and opinions contained in the JOURNAL OF PETROLEUM TECHNOLOGY are, unless otherwise indicated, attributable only to the author, and do not necessarily reflect the views of the AIME, its officers, committees, or other agencies.

The AIME also publishes:
Mining Engineering
Journal of Metals

OFFICERS of the PETROLEUM BRANCH

Chairman
Paul R. Turnbull
La Gloria Corp.
Corpus Christi, Texas

Vice-Chairmen

Morris Muskat
Gulf Oil Corp.
Pittsburgh, Pa.

John R. McMillan
Fullerton Oil Co.
Pasadena, Calif.

EXECUTIVE COMMITTEE

John S. Bell
Humble Oil & Refining Co.
Los Angeles, Calif.

D. V. Carter
Magnolia Petroleum Co.
Dallas, Texas

R. C. Earlougher
Earlougher Engineering
Tulsa, Okla.

Thomas C. Frick
Atlantic Refining Co.
Midland, Texas

E. N. Van Duzee
Shell Oil Co.
New Orleans, La.

G. L. Yates
Amstutz & Yates
Wichita, Kansas

Richard W. French
Sohio Petroleum Co.
Cleveland, Ohio

Charles R. Dodson
University of Southern California
Los Angeles, Calif.
Representing M.I.E.D.

Louis C. Raymond
Ford, Bacon & Davis, Inc.
New York, N. Y.
Representing M.E.D.

Treasurer
W. E. Stiles
Buffalo Oil Co.
Dallas, Texas

Executive Secretary
Joe B. Alford
AIME
Dallas, Texas

Counsel
Robert E. Hardwicke
Hardwicke, HadJaway & Pope
Fort Worth, Texas

COMMITTEE CHAIRMEN and VICE-CHAIRMEN

Publications
John P. Hammond
Amerada Petroleum Corp.
Tulsa, Okla.

Membership
Jack M. Moore
Dowell Incorporated
Midland, Texas

Economics
Kenneth E. Hill
Chase National Bank
New York, N. Y.

Production Review
E. H. Berlin, Chairman
Standard-Vacuum Co.
New York, N. Y.

R. B. Gilmore, Domestic
DeGolyer & MacNaughton
Dallas, Texas

A. H. Chapman, Foreign
Arabian American Oil Co.
New York, N. Y.

Advertising
Bruce Barkis
B & W, Inc.
Houston, Texas

Technology
Douglas Ragland, Chairman
Humble Oil & Refining Co.
New Orleans, La.

Jack H. Abernathy, Drilling
Big Chief Drilling Co.
Oklahoma City, Okla.

E. P. Hayes, Production
The Texas Co.
Houston, Texas

W. H. Justice, Gas
La Gloria Corp.
Corpus Christi, Texas

Milton E. Loy, California
Schlumberger Well Surveying Corp.
Los Angeles, Calif.

Nominating
Richard W. French
Sohio Petroleum Co.
Cleveland, Ohio

Education
John C. Calhoun, Jr.
Pennsylvania State College
State College, Pa.

Student Activities
W. S. Morris
East Texas Salt Water Disposal Co.
Kilgore, Texas

OFFICERS OF THE AIME

President, Michael L. Haider; Vice-Presidents, L. F. Reinartz, Philip Kraft, R. W. Thomas, J. L. Gillson, O. B. J. Fraser and James B. Morrow; President-Elect and Treasurer, Andrew Fletcher; Past-President, W. M. Peirce; Secretary, E. H. Robie.

No "SHIP-IN-[illegible]TTLE" construction on a Lufkin TWO-PIECE GEAR HOUSING

Plenty of "BEEF" throughout which is typical LUFKIN DESIGN POLICY

Provides easy accessibility for assembly and inspection

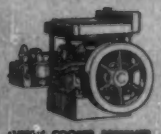
- Allows main gear to be assembled on shaft with heavy 60 ton pressed fit. All rotating parts easily set in place before cover is bolted on. No "threading" of shafts and bearings as necessitated by solid gear box with no split.
- Made of High Tensile Lufkaloy-Iron heavily ribbed inside, giving smooth exterior, pleasing in appearance and easy to keep clean.
- Large Heat Treated Alloy Steel Studs capable of carrying ten times rated load without stretching.
- Large Clean Out Hole for removing sludge from bottom of box.

LUFKIN, TEXAS

Branch sales and service Houston, Dallas, New York, Tulsa, Los Angeles, Seminole, Oklahoma City, Corpus Christi, Odessa, Kilgore, Wichita Falls, Casper, Wyoming, Great Bend, Kansas.

Lufkin Equipment in CANADA is handled by

THE LUFKIN MACHINE CO., LTD., 14321 108th Avenue, Edmonton, Alberta, Canada.



LUFKIN OIL FIELD AND INDUSTRIAL TRUCK TRAILERS

INDUSTRIAL SPEED REDUCERS AND INCREASERS

DIVISION LUFKIN FOUNDRY & MACHINE COMPANY INDUSTRIAL, MILL AND AUTOMOTIVE SUPPLIES

JOURNAL OF
Petroleum Technology

Vol. V JANUARY, 1953 No. 1

B and W Inc.
SCRATCHERS AND CENTRALIZERS FOR A good CEMENT JOB

CONTENTS

Editorial Features — Section 1

San Ardo — A Geologic Case History, by T. A. Baldwin 9

San Ardo — A History of Development, by H. O. Miller 11

An Improved Method of Mounting Core Specimens in Lucite, by R. E. Barrett and I. Fatt 14

Technical Note: Compressibility of Reservoir Rocks, by Howard N. Hall 17

Technical Note: Effect of Quick-Freezing vs Saturation of Oil Well Cores, by Frank C. Kelton 21

Program of Petroleum Branch Activities, 1953 Annual Meeting . . . 25

Abstracts of Papers to be Presented, 1953 Annual Meeting . . . 26

Petroleum Transactions

Equilibrium Constants for a Gas-Condensate System, by A. E. Hoffmann, J. S. Crump and C. R. Hocott 1

Permanent-Type Well Completion, by T. A. Huber and G. H. Tausch 11

The MicroLaterolog, by H. G. Doll 17

Institute Affairs — Section 2

Petroleum Branch Affairs, by Joe B. Alford 1

Employment Notices 3

Petroleum Branch Membership 4

Personals 6

Advertisers' Index 8

THIS MONTH'S COVER

The search for oil-bearing formations goes on in Canada in the face of extreme weather conditions. Here a driller's helper chops a hole in an ice-covered stream near Mayerthorpe, Alberta, to fill his tank truck. Later the frigid water will be used in the drilling of shot holes.

Photo by Standard Oil Co. (N. J.)

B and W LATCH-ON CENTRALIZER

With the NEW KON-KAVE BOW, Drop forged from the finest alloy spring steel.

B and W MULTI-FLEX SCRATCHER

Scratches on the upstroke after casing reaches bottom.

B and W HINGED NU-COIL SCRATCHER

The coil spring, reversible scratcher. Economical and easiest to install.

B and W ROTATING SCRATCHER

Cover the critical section — rotate until the cement is placed.

B and W Incorporated
Well Completion Specialists
WEST COAST 3545 Cedar Avenue
Long Beach 7, California, Long Beach 4-8366
GULF COAST P. O. Box 5266
Houston 12, Texas, Phone WEntworth 6603

BAKER

now offers not one, not two, but THREE ranges of

Hinge-Lok Casing Centralizers

. . . with increased reach (bowed height) of springs to provide AMPLE ALL-AROUND cementing space for ALL casing programs, and VARYING hole sizes and conditions, PLUS unsurpassed convenience and ease of installation.

BAKER MODEL "H"
20 Range HINGE-LOK
Casing Centralizer

PRODUCT NO. 9112

Recommended where LESS-THAN-NORMAL CLEARANCE exists between the casing ON which the centralizers are mounted and the casing THROUGH which the centralizers are run. If the formation is such as to create special problems of over-size or irregularity of the open hole, it is often advisable to run the "H-20" Centralizer on the first few joints—for ease in starting—followed by the "H-25" or the "H-50" Super-Range Centralizer.

BAKER MODEL "H"
25 Range HINGE-LOK
Casing Centralizer

PRODUCT NO. 9113

Recommended where NORMAL CLEARANCE is present, and no serious problem of over-size hole is anticipated. The "H-25" Centralizer is recommended where conditions are such that starting force would be a problem with the "H-50" Super-Range Centralizer, in which case the H-25 might be used on the first few joints and the H-50 run above it. Although the H-50 requires a larger spacing interval for easy starting than the H-20 or the H-25, fewer "H-50" Centralizers—with their superior reach—ensure even greater effective centering force.

"Reach" (Bowed Height) is vital factor

All Baker HINGE-LOK Casing Centralizers have greater reach (or bowed height) of springs in corresponding ranges than any other casing centralizers on the market.

Increased reach means adequate, all-around cementing space even though the hole size varies considerably from the drill bit size. Without this increased reach, it is quite probable that casing may contact the wall of the hole between centralizers resulting in a poor cement job at that point.

Hinged for easy mounting

Baker HINGE-LOK Casing Centralizers can be *installed in a matter of seconds* while running-in, as *no welding is required.* Just close the HINGE-LOK Centralizer *around a coupling* and then insert drive nails which *thread themselves* into the hinge knuckles, and *will not come out.* When exact spacing is desired, easily installed Stop Rings can be plug-welded at required positions.

Maximum effective centering force

Baker HINGE-LOK Casing Centralizers provide the most uniform annular cementing space around the casing. And this cementing space is present regardless of repeated flattening of the springs in a deep well, or of off-vertical condition of the hole.

The engineered bow shape of the springs, with an ideal relationship between the length and the bowed height of the springs, provides *greater landed centering force* than can be obtained from any other available hinge-type centralizer covering the same range of hole sizes.

All springs work together

All of the powerful springs of Baker HINGE-LOK Casing Centralizers work together to offer a combined positive resistance against any tendency of the casing to contact the wall of the open hole. As the springs are forced toward the casing by contact with the wall of the hole, their effective length is decreased, thereby stiffening them and increasing their resistance to further deflection.

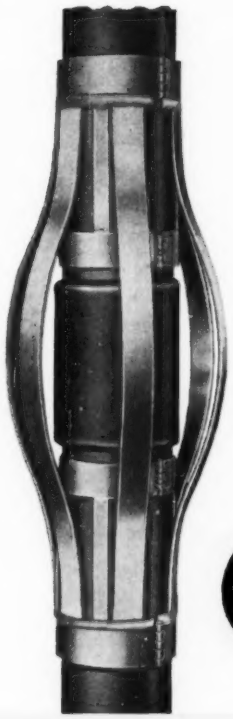
Unlimited rotation of casing

Whether Baker HINGE-LOK Casing Centralizers are installed around couplings or over a standard Stop Ring, the casing can be freely rotated without rotation of the centralizers.

Easy starting without snubbing

The superior spring design of Baker HINGE-LOK Casing Centralizers assures easy starting without sacrificing the powerful centering force delivered after full down-hole travel of the casing. By following the easily read "Starting Force Spacing Guide," all need for applying external starting force is eliminated even in relatively close-tolerance programs.

20 RANGE



25 RANGE

SUPER-RANGE

BAKER MODEL "H-50"
Super-Range HINGE LOK
Casing Centralizer

PRODUCT NO. 9114

Recommended for GREATER-THAN-NORMAL CLEARANCE—wherever the diametral clearance between the casing ON which the centralizers are mounted, and the casing THROUGH which they are run exceeds five inches, or for NORMAL CLEARANCE where extensive hole irregularities are anticipated. No other centralizer can provide such effective centering action as the "H-50" in *irregular or over-size hole sections, or in cavities.* By increasing the bow of the springs (without proportionately increasing their resistance to starting) maximum centering efficiency is assured, regardless of individual well conditions.

BE SURE YOU GET

Maximum Centering Force

THROUGHOUT THE ZONE

TO BE CEMENTED

Always *pulled*—never pushed

Baker HINGE-LOK Casing Centralizers are always "pulled" during upward or downward travel of the casing in the well. This feature is important when the centralizer passes through any tight spots in the hole—and is especially advantageous when reciprocating casing during cementing operations.

Call Baker for Centralizer service

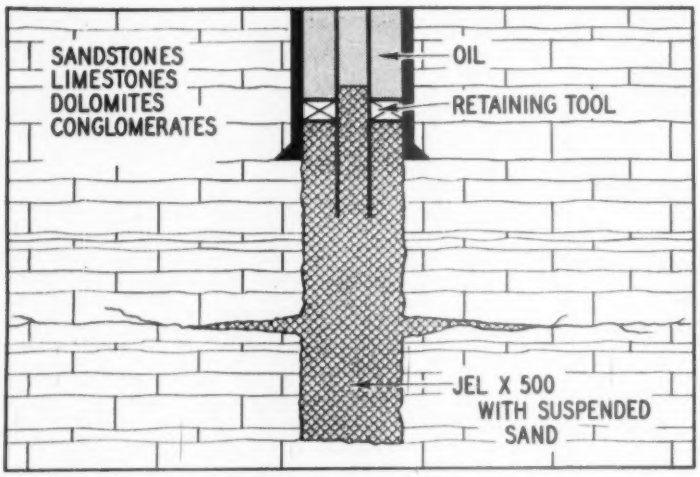
Any Baker representative, or office, is ready to give you the kind of service every operator appreciates—sincere, courteous assistance to help you get successful "first-time" cementing results.

BAKER OIL TOOLS, INC.

HOUSTON • LOS ANGELES • NEW YORK

PRODUCTION INCREASED 26 BOPD WITH DOWELL STRATAFRAC

New Dowell Service Combines Advantages of Acidizing and Fracturing in Single Treatment



This well's initial production was 19 BOPD. While the well had not declined, it was not considered good for its location. After various other remedial methods had failed, a Dowell Stratafrac treatment increased oil production to 45 BOPD. Payout time was estimated at 36 days.

Stratafrac treatments using Jel X 500 have increased production from all types of oil bearing formations—limestone, dolomite, sandstone, chat and conglomerate. This service is designed to fracture and acidize the formation in a single operation.

Stratafrac treatments carry suspended sand into existing fractures as an abrading and propping agent. They are also designed to remove paraffin or other heavy hydrocarbons present in the fractures or formation.

Stratafrac treatments are engineered to save you money by holding rig time to a minimum. All materials arrive at the well ready-mixed. No jel-breaker solution is needed following Stratafrac treatments, as the material returns to the well bore as a thin, free-flowing liquid. The well can be returned to production immediately without costly shut-in time.

GET THE FACTS ON STRATAFRAC! Find out how Stratafrac has increased production in many fields. For a more detailed discussion on this new Dowell service, call your nearest Dowell station or write direct to Tulsa, Dept. A15.

DOWELL SERVICE

Acidizing • Jel X* • Electric Pilot • Perfo Jet
Paraffin Solvents • Jelflake® • Bulk Inhibited Acid
Chemical Cleaning for Heat Exchange Equipment.

DOWELL INCORPORATED • TULSA 1, OKLAHOMA
A Subsidiary of The Dow Chemical Company
"First in Oilfield Acidizing . . . Since 1932"

*Service Mark.

Look to **DOWELL**
FOR OIL INDUSTRY CHEMICAL SERVICE

SAN ARDO FIELD — A Geologic Case History

By T. A. Baldwin
Monterey Oil Co.

ABSTRACT

San Ardo Field is the world's largest known commercial reserve of heavy oil: probably the largest addition to Pacific Coast reserves in the last ten years. Discovery of this vast accumulation resulted from persistent geologic studies and courageous drilling. Geology has also played a dominant role in analyzing peculiarities of the reservoir.

INTRODUCTION

The present and future development of the field will undoubtedly be planned by a close liaison of geologic and engineering techniques.

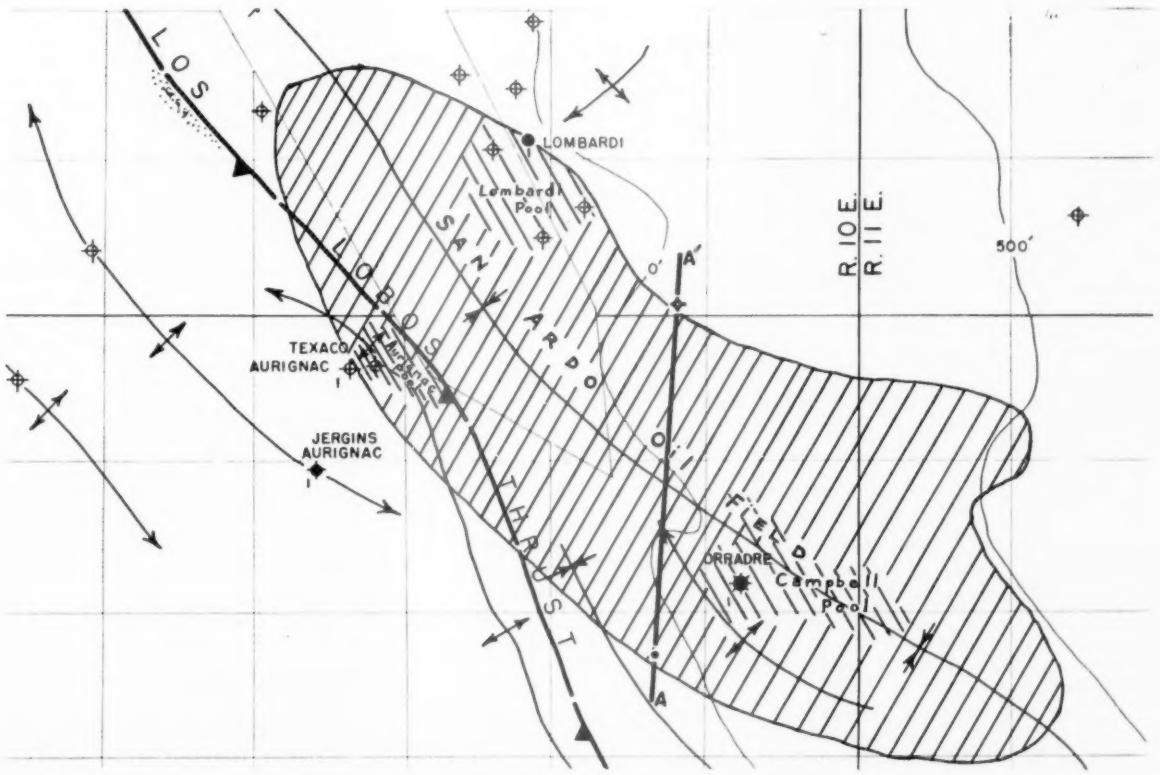
The first significant commercial production from the San Ardo Field in the Salinas Valley of California was established by Jerkins Oil Co., Orradre No. 1 on May 18, 1948. A long history of geologic thought and drilling effort predated this production. The principle links in the chain of discovery were as follows:

Surface tar sands near San Ardo led to a number of shallow, dry holes between 1900 and 1920. Several of these early wells reported oil shows.

Careful geologic mapping of the western side of the Salinas Valley (including the area of the oil seeps) and detailed study of the old wells led field geologists, during the 1940's, to draw a hypothetical Upper Miocene shoreline through the San Ardo area. It was hoped that sands deposited along this shore line would have greater permeability than had been observed in the Salinas Valley up to that time. It was presumed that a trap might exist where such sands lapped upon granite.

Texas Co. exploratory wells (Aurignac 1 and 2A), drilled to test the supposed shoreline on a favorable surface structure, encountered loose sands, of extreme permeability, saturated with very viscous heavy crude. These wells were within what later became known as the "Aurignac Pool;" because of uncontrollable sanding they failed to produce from conventional liners or gun perforations.

Encouraged by these Texas Co. wells, the Jergins Oil Co. and North American Oil Consolidated tested the same Miocene shore line on a separate surface structure, finding a few feet of saturation in Rosenberg No. 1. This was the first show in the area that later was called the "Lombardi Pool."



After further detailed surface mapping, the Texas Co. Lombardi No. 1 was drilled and completed with a gravel packed liner to make the first oil production in the Salinas Valley. This well shortly went to water.

Successive tests up-dip from Lombardi No. 1 by Jergins Oil Co.' (McCool 23-35, McCool No. 1, McCool 3-1, McCool 3-2) found the Lombardi sand increasingly wet at higher and higher structural positions. This indicated that a sharply inclined water table was a main problem in the area.

Moving far down the regional dip, Jergins drilled Orradre No. 1 on a local high at a point where it was anticipated that the water table was very low. Orradre No. 1 discovered a gasser on the crest of what may well prove to be the largest addition to California's reserves in the last ten years. The area around Orradre No. 1 became known as the "Campbell Pool."

HISTORY

The events listed above show the San Ardo discovery to be the result of original surface geology backed by persistent and courageous exploration drilling combined with shrewd, imaginative subsurface geological interpretation of that drilling while it was in progress.

During a period of only 22 months, from the summer of 1946 until May, 1948, two operators had drilled, in the exploratory campaign, a grand total of 15 wells pertinent to the discovery. This was an example, possibly unique, of geological persistence in backing scientific judgment.

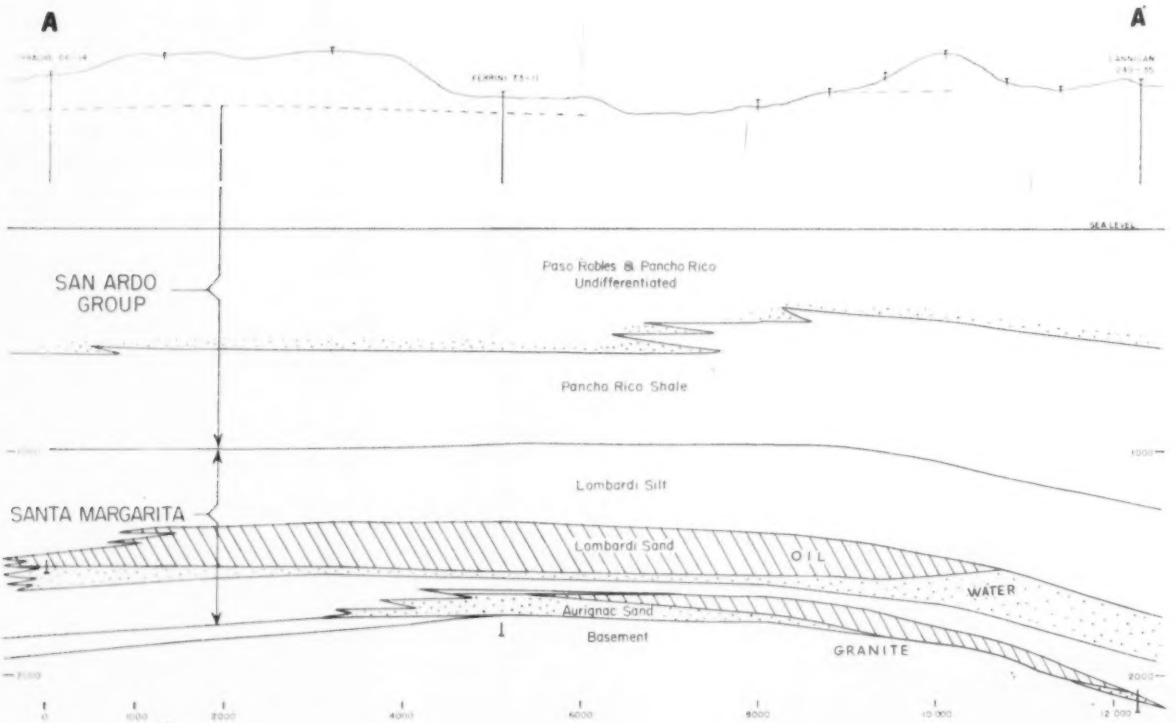
After Orradre No. 1, San Ardo continued to be plagued for some time by serious problems in control of water, gas and sand. Each of these challenges was met by long-term geologic studies of the reservoir.

The principle productive horizon at San Ardo is the Lombardi sand, a remarkably uniform body in which oil, water, and gas occur, not separated by the slightest shale barriers. Early, sad experiences demonstrated repeatedly that water and gas could cone through the oil sand vertically for 20 ft or more. Studies of gas-oil and oil-water interfaces had, therefore, to be maintained with unusual refinement in order to predict accurately the irregularities of these intervals. In work of this type it is not sufficient to know where the oil-water contact has been established; it is, in fact, required to know why it is there; for the cause of the warping is the clue to water table location in the unexplored part of the field.

Geologic analysis has shown that San Ardo oil was originally trapped at the up-dip shale edge of Upper Miocene shoreline sands. Originally oil had been anticipated at the "buttressed" edge where the sands lap upon the granite. This edge has proven non-productive due to lack of a seal against the granite. The Lombardi water table has been defined as an irregular synclinnally warped surface and has been contoured on a 10-ft interval. The warping of this water table has been shown to be the result of structural warping which occurred in Pleistocene and Recent time.

Geological correction for these post-accumulation warps has made it possible to portray the ancestral structure upon which this gigantic oil accumulation occurred — a broad easterly plunging anticlinal nose with Upper Miocene sands changing to shale up-dip. When the original nature of the accumulation had been deciphered it became possible to predict oil saturation isopachs far beyond the edge of development of the field. Continued drilling at San Ardo was controlled by this technique. Many outpost wells a half mile or more beyond the edge of the field have found the prediction of oil sand thickness

Continued on Page 5, Section 2



SAN ARDO FIELD — A History of Development

By H. O. Miller
The Texas Co.

ABSTRACT

Experience gained in early development showed the necessity of completing wells with gravel packed slotted liners. It also showed that water coned up rapidly and that wells should be bottomed a considerable distance above the water table. Lombardi Sand producers are bottomed a minimum of 75 ft and Aurignac wells a minimum of 50 ft above water. It is necessary to cement the casing approximately 20 ft below the gas-oil interface to prevent downward coning of gas.

Lost circulation is experienced to a depth of approximately 500 ft in the hills west of the Salinas river. It was necessary to provide protection from high water in the river bottom. Wells have been deflected as much as 500 ft under the river without difficulty.

The Lombardi Sand has a gas cap 20 ft in thickness and a maximum oil column of 230 ft. Its average porosity is approximately 33 per cent and its permeability is approximately 4,000 md. This crude varies in gravity from 10.6° to 12.1° API at 60°F. Its viscosity is 300,000 Saybolt Universal Seconds at 80°F and its pour point is 55°F. Gas-oil ratios vary between 15 and 100 cu ft/bbl. The original bottom hole pressure was approximately 900 psi. The 242 Lombardi wells completed to date have produced approximately 5,400,000 bbl of oil.

Two small gas cap areas exist in the Aurignac Sand. These are not well defined. This sand reaches a maximum productive thickness of approximately 200 ft. Its average porosity is approximately 30 per cent and the average permeability is approximately 1,350 md. The crude gravity varies from 12° to 13.5° API at 60F°, whereas its viscosity is 26,000 Saybolt Universal Seconds at 80°F. Its average gas-oil ratio is approximately 85 cu ft/bbl. The bottom hole pressure of the Aurignac reservoir was approximately 1,000 psi originally. The 116 Aurignac wells now completed have produced approximately 2,300,000 bbl of oil.

Surface facilities have been specially designed to handle these low gravity high viscosity crudes. Lead pipes are designed to provide for individual well gauges. Pumping equipment is installed initially with electric motors for prime movers.

It is necessary to heat the oil to 180°F to break down the foam and facilitate shipment. Four bbl of storage are required for each daily barrel of oil produced. Stock tanks are insulated and provided with steam coils.

Hot crude oil is blended with gas oil cutter stock when delivered to the pipeline. An eight-in. pipeline delivers blended crude to Estero Bay and a four-in. line returns cutter stock to San Ardo.

INTRODUCTION

This paper gives a brief history and discussion of the problems encountered in the development of the San Ardo Field, in the Salinas Valley of California.

DEVELOPMENT

The experience gained in early wells was a direct benefit in later development. The Texas Co. Aurignac 1 and 2A showed the necessity of a special completion practice to control sand. It was decided therefore to gravel pack the liner in The Texas Co. Lombardi 1. Although this well has since proved to be of subcommercial value it was the first oil producer in the San Ardo Field.

Seven wells were completed in what is known as the Lombardi area. Early experience in this area indicated that water cones vertically from 30 to 50 ft in a very short period of time. It is therefore necessary to bottom wells a considerable distance above the water table. A similar condition was found in early completions in the Campbell area.

Jergins' Orradre 1 discovered commercial production in the Lombardi Sand in what is now considered the Campbell area. Experience gained in completion of this well aided materially in future development programs. The well encountered approximately 90 ft of oil saturated sand. The top of the sand appeared to have a low oil saturation. Upon completion after gravel packing, the well produced dry gas with no accompanying oil. Although only 20 ft of gas sand was open in the hole above 70 ft of oil sand, the difference in viscosities allowed only gas to enter the hole. Wells with casing set immediately below the gas-oil interface produced with very high gas-oil ratios shortly after completion. It has been found that by setting casing 20 ft below this gas-oil contact downward coning of gas is eliminated.

Early development in the San Ardo Field progressed slowly. All oil was trucked out from the field approximately 60 miles to the Union Oil Co.'s pump station at Santa Margarita. In the latter part of 1950 General Petroleum Corp. announced that they planned to lay a pipeline into the San Ardo Field. At the present time General Petroleum Corp. has 29 Aurignac producers and 140 Lombardi Sand producers. The Superior Oil Co. has nine Aurignac Sand producers and The Texas Co. has 77 Aurignac Sand producers and 102 Lombardi Sand producers. Pacific Western Oil Co. has one Aurignac Sand producer. There are, therefore, a total of 358 producing wells in the field.

DRILLING PROBLEMS

The area west of the Salinas River, which is underlain by productive Aurignac Sand, is of rugged topography necessitating expensive roads and rig sites. Considerable thought and study were given to the possibility of directionally drilling more than one well from one rig site. However, due to the shallow depth of the producing sand it was found that this was not practical. The hills on the west side of the river are a direct reflection of the King City or Los Lobos Thrust fault which outcrops along the edge of the Salinas River in this area. Many minor faults and fractures occur in the surface

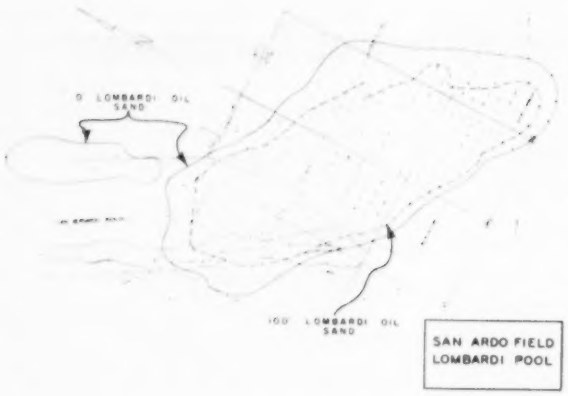


FIG. 1 — LOMBARDI POOL LIMITS AND 100 FT ISOPACH.

beds in these hills causing considerable difficulty with lost circulation while drilling the surface holes. This has necessitated setting approximately 500 ft of surface casing throughout this area. Although the beds are distorted below the fault no lost circulation occurs.

In the river bottom area east of the Salinas River bed itself it has been necessary to protect locations from storm damage during high water. Approximately one and one-half miles of levee was built along the edge of the river to control its course during high water. Wells drilled from this levee have been whipstocked under the river bed in order to obtain uniform drainage. They have been deflected to as much as 500 ft horizontally without difficulty. The highest angle obtained so far is approximately 20° and no particular problems have been found in producing wells at this angle, even though the gravity of the crude and viscosity are such that it might be expected. In this part of the field river gravels extend to a considerable depth, and therefore 200 ft of surface casing has been used.

In the area to the east of the river bottom, in what is known as the Orradre Hills, the surface beds consist of consolidated sands and shales requiring only 100 ft of surface casing. The size and type of the surface casing used has varied due to the steel shortage.

No other unusual hazards have been encountered in the actual drilling of wells in the San Ardo Field. Approximately four to six days are required for the actual drilling and from seven to ten days total time are usually required. It is the general practice to drill 11-in. hole below the surface casing to the top of the producing sand. At this point the hole is reduced to 8½ in. throughout the sand interval. Eight and five-eighths-in. casing is cemented on top of the oil sand.

Development has followed a 10-acre spacing pattern for both the Aurignac and Lombardi Sands.

Development of the Lombardi Sand has been carried out within the 100-ft isopach. With an exception of a few wells completed early in the life of the field all the wells are within this area. This policy has been followed in order that the total depth of the holes will be at least 75 ft above the water table. This allows approximately 25 ft of penetration in wells around the periphery of the field. By maintaining a safe distance of 75 ft above the water table it is felt that the upward coning of water will be minimized. There are two policies being followed with regard to penetration of the Lombardi Sand. One operator feels that it is safe to complete all wells within 75 ft of the water table, thereby penetrating as much as 155 ft of production sand. Another operator feels that it is much safer to penetrate the producing sand only 30 to 40 ft thereby keeping the bottom of the hole as much as 190 ft above the water table.

The amount of penetration taken by wells producing from the Aurignac Sand is dependent upon their position in relationship to bottom water. There is a considerable area of Aurignac Pool where oil sand rests immediately on the granite basement and no bottom water exists. Wells within this area are completed with full penetration in order to obtain the greatest amount of drainage. Aurignac wells completed outside of this area where there is an oil-water interface are generally completed approximately 50 ft above the water table. It is felt that the lower viscosity of the Aurignac oil as well as silty tight lenses in the sand will greatly reduce the amount of coning as compared with that experienced in early completions in the Lombardi Sand.

Two completion fluids are used in the field. One operator uses Limed Impermex mud to clean out after cementing casing and to underream the sand face to 13½ in. Another operator uses Oil Base drilling fluid for this same operation. Early in the development of the field some prepack liners were used. There were found unsatisfactory, however, and at the present all wells are completed with flowpack liners. Six and five-eights-in. slotted liners are generally used with 100 (oilfield) mesh slots throughout the major portion of the producing zone. Approximately five ft of 60 mesh slots are placed immediately below the casing shoe and lap inside of the 8⅝-in. casing. This 60 mesh section of liner is used to reduce sand entry in case the gravel settles during production. Gravel sizes vary somewhat throughout the field. Three-sixteenths by one-quarter in. is used by one operater whereas another operator uses 3/32 x ⅛-in. gravel.

RESERVOIR

Lombardi Sand

The Lombardi Sand is approximately 260 ft in thickness on the top of the structure. As explained previously, there are approximately 20 ft of gas sand on top of the structure and approximately 230 ft of oil sand thickness. The remaining sand is, of course, water bearing. This sand is soft and uncon-

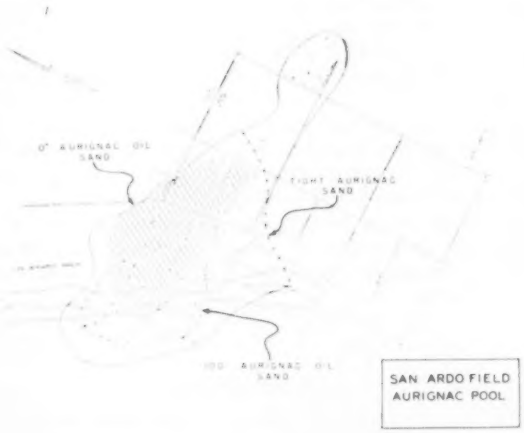


FIG. 2 — AURIGNAC POOL LIMITS AND WATER BUTTRESS LINE.

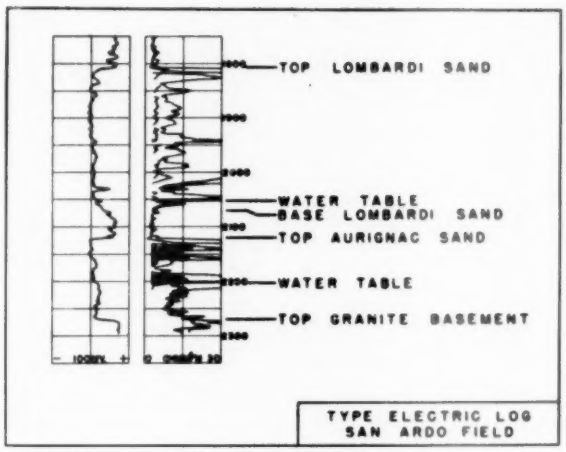


FIG. 3 — TYPICAL ELECTRIC LOG.

solidated and has an average porosity of approximately 33 per cent and an average permeability of approximately 4,000 md. The crude oil produced from the Lombardi Sand has a gravity ranging from 10.6° to 12.1° API at 60°F. The viscosity of this crude at 80°F is 300,000 Saybolt Universal Seconds. Its pour point is 55°F.

Accurate figures are difficult to obtain on the amount of dissolved gas in the Lombardi crude. Gas-oil ratios vary from approximately 15 cu ft/bbl to 100 cu ft/bbl.

The original bottom hole pressure of the Lombardi Sand was approximately 900 psi. It is difficult to obtain bottom hole pressures in the San Ardo Field. Since all wells are equipped with pumping equipment when originally completed, it would be thought that annulus runs could be made very readily. However, the viscosity of the crude oil is such that a bottom hole pressure bomb run on a wire line will not sink in the fluid. It is therefore necessary to pull rods and run the bombs on the rods. This is, of course, a costly procedure and therefore the program for pressure surveys throughout the field is on a six months' basis with only key wells measured.

There is insufficient data to determine the drive mechanism for this reservoir. It is probable, however, that a water drive exists. The Lombardi Sand has produced to date approximately 5,400,000 bbl of oil.

The Lombardi Sand water table is tilted approximately 160 ft in the 4½ miles in the productive length of the field. The interface has only minor irregularities and it was therefore possible to determine its position readily by drilling certain key wells to a sufficient depth to find water. Approximately one well in 120 acres was drilled through the Lombardi and Aurignac Sand to determine their water tables. From the data thus obtained the correct penetration could be determined for subsequent wells.

Aurignac Sand

The Aurignac Sand water table is tilted similarly to that of the Lombardi Sand but is much more irregular. This irregularity is undoubtedly due to a greater degree of variance in permeability. In many areas the basal part of the Aurignac Sand becomes quite silty and therefore it is difficult to determine from the electric logs what is actually water bearing. It has been necessary in many cases to make formation tests to determine if actually water would be produced from one of these tighter sections. The productive Aurignac Sand reaches a maximum thickness of approximately 200 ft, in the vicinity of The Texas Co. Labarere Lease on the west side of the Salinas River. A small gas cap exists in this part of the field. There is also a gas cap area in this sand in the vicinity of General Petroleum Corp.'s Ferrini Lease. The sand in this vicinity, however, is quite silty in character and is not considered to be commercial. Since there has been little development of the Aurignac in this area it is difficult to define the gas cap and the oil-water interface.

This sand has an average porosity of approximately 30 per cent, and an average permeability of approximately 1,350 md. The character of the crude is slightly better than that of the Lombardi Sand, its gravity varying from 12° to 13.5° API at 60°F. The viscosity is 26,000 Saybolt Universal Seconds at 80°F. The gas-oil ratio varies considerably as it does in the Lombardi Sand but it is thought to have an average of approximately 80 cu ft/bbl. The bottom hole pressure was approximately 1,000 psi originally. Here again the type of drive is not known but it is probably a water drive. The Aurignac Sand has produced approximately 2,300,000 bbl of oil.

SURFACE FACILITIES

Surface equipment for the San Ardo Field has been designed particularly to handle this low-gravity, high-viscosity crude. Pumping units have torque ratings from 57,000 to 80,000 in. lb. The entire field is electrified at this time with 7½ and 10 HP motors. A few five HP motors have been installed on wells having lighter loads. Aurignac Sand wells have a production allocation of 100 B/D and Lombardi Sand producers 90 B/D. This is easily obtained with 24-in. strokes at a speed of eight to ten strokes per minute. Both sands are actually capable of flowing in their early life. However, this does not last over any period of time and therefore pumping equipment is installed initially. Many Aurignac wells are capable of flowing as much as 300 B/D initially while some Lombardi wells will flow from 30 to 50 B/D of oil. This flowing condition will probably not exist during the cold winter months since lead lines will become cold and the viscosity will rise and retard production.

When pumping is resumed after a shut-down period it takes about 30 minutes before a full stroke can be obtained with the pump. During this time the rods drop very slowly due to the high viscosity of the cool oil in the tubing.

Lead Line Design

The high viscosity of the crude has again required special planning for lead line design. During the cold winter period lead line pressures at well heads are frequently as high as 500 or 600 psi. Occasionally 1,000 psi lead line pressures have been noted.

Theoretical calculations of line size and length were compared as closely as possible with actual pressures, temperatures and flow rates obtained in the field. This did not give an exact formula but did materially aid in determining the length and sizes necessary to operate at pressures not to exceed approximately 500 psi. The basic pattern was designed to serve 160 acres or 16 wells. Four radiating six-in. trunk lines are paralleled by four-in. gauge lines. Lateral four-in. lines connect each well to the end of the trunk and gauge lines through a manifold. In some cases it has been possible to extend the lines to service a greater area.

Tank Batteries

Although there is a very small volume of gas dissolved in the crude the high viscosity causes serious foaming difficulties in the tanks. Heating to 180°F or 190°F is necessary to degas

Continued on Page 5, Section 2

FIG. 1 — PROCEDURE FOR MOUNTING CORE SPECIMENS IN LUCITE.

An Improved Method of Mounting Core Specimens in Lucite

R. E. BARRETT AND I. FATT, MEMBER AIME, CALIFORNIA RESEARCH CORP., LA HABRA, CALIF.

The method of mounting core specimens in Lucite described by Showalter[1] is usually useful and convenient. When mounting large or irregularly shaped core specimens, however, the large blocks or cylinders of Lucite required by Showalter's method are expensive and difficult to obtain. This article describes a modification of Showalter's method in which only thin walled Lucite tubing and Lucite molding powder are required. The procedure used is shown pictorially in Fig. 1. A thin walled Lucite tube, slightly larger than the final mounting desired, is closed at one end by cementing on a Lucite disk. A convenient cement can be made by dissolving Lucite molding powder in Lucite cement No. H-112 to give a thin syrup. After the cement is dry, the core is centered in the tube and the annular space is filled with Lucite molding powder (Lucite Powder No. HG-40 was used). The tube is tapped vigorously while adding the powder to give minimum porosity. The filled tube is then capped by cementing on a Lucite disk.

After the cement is dry, the tube is placed in the pressure-temperature bath described by Showalter. The temperature is raised to 250°F and kept at this temperature for one hour without pressure. Gas pressure of 1,000 psi is then applied for four hours. The bath is then cooled to room temperature while maintaining pressure. After releasing the pressure, the mounted specimen can be removed and machined as desired. A mounted and machined core is shown in Fig. 2.

FIG. 2 — MOUNTED AND MACHINED CORE.

Reference

1. Showalter, W. E.: "Mounting Core Analysis Specimens in Thermoplastic," *Jour. Petr. Tech.*, (Dec. 1950), 8. ★ ★ ★

Manuscript received in the Petroleum Branch office Nov. 21, 1952.

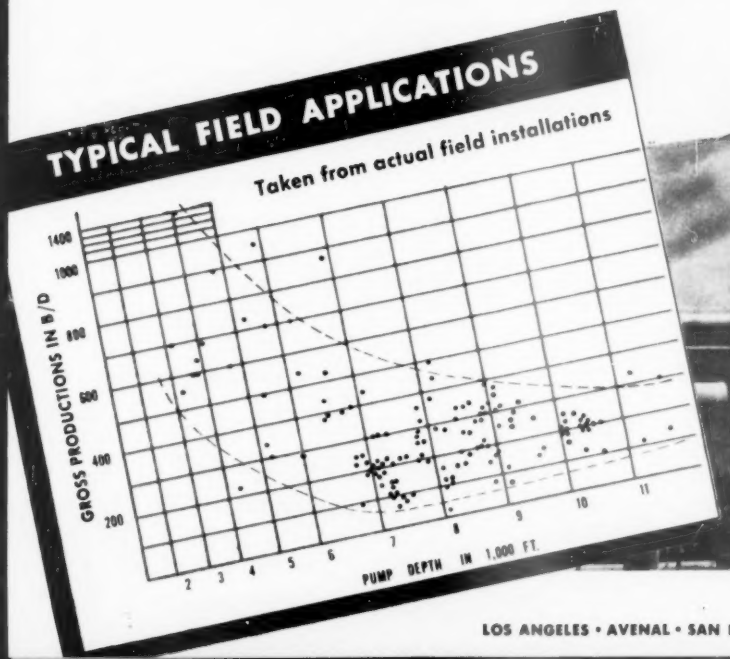
PELTON *here's where long stroke hydraulic pumping belongs*

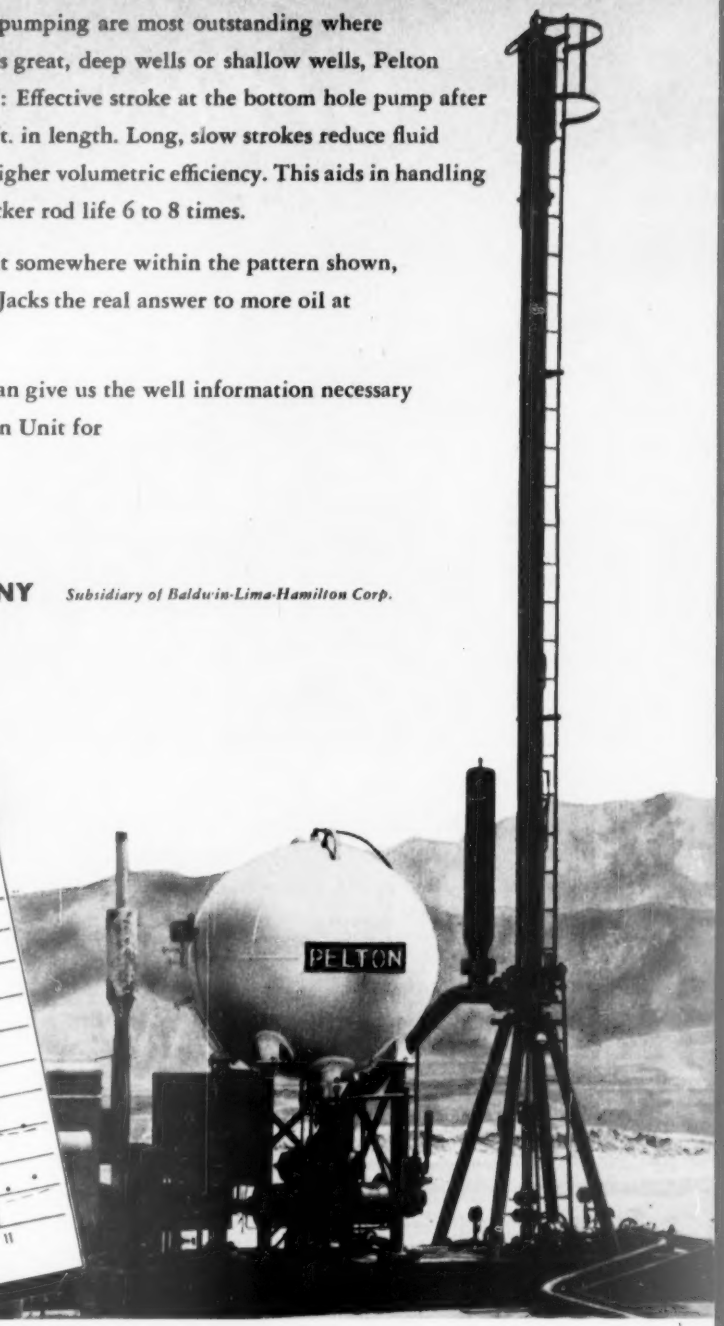
The economics in favor of Long Stroke Hydraulic pumping are most outstanding where pumping loads are heavy. Wherever oil potential is great, deep wells or shallow wells, Pelton Long Stroke Units pay off quickly. THE REASON: Effective stroke at the bottom hole pump after rod stretch permits use of a pump barrel 10 to 30 ft. in length. Long, slow strokes reduce fluid velocity through the standing valve resulting in higher volumetric efficiency. This aids in handling gassy or sandy fluids. Soft rod reversals prolong sucker rod life 6 to 8 times.

Check the application chart below. If your wells fit somewhere within the pattern shown, you will find Pelton Long Stroke Hydraulic Pump Jacks the real answer to more oil at less pumping cost.

Send for our application data sheet on which you can give us the well information necessary to determine the correct model and price of a Pelton Unit for your job—no obligation whatever.

THE PELTON WATER WHEEL COMPANY *Subsidiary of Baldwin-Lima-Hamilton Corp.*
OIL INDUSTRY MACHINERY DIVISION
2447 East 54th Street, Los Angeles 58, California

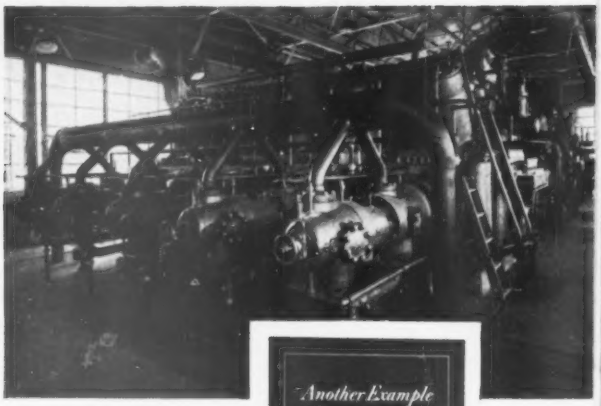




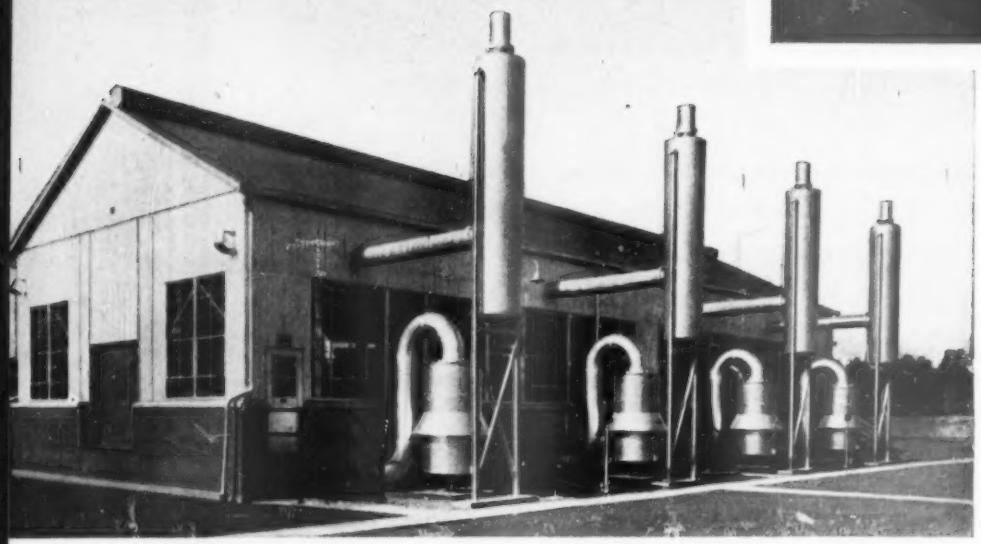
LOS ANGELES • AVENAL • SAN FRANCISCO • DALLAS • ODESSA • HOUSTON • NEW YORK • PHILADELPHIA

In Oklahoma Natural's largest gas-storage project . . .

. . a lot of compressing in small space with compact GMV's



Another Example of Efficient Power at Lower Cost



● Look at the size of the building . . and the neat compactness of this 4400-hp GMV compressor set-up. Here, at Depew, Oklahoma Natural Gas Company is equipped to handle approximately 160,000,000 feet per day with a suction pressure of 500# and a minimum injection pressure of 800#—a lot of compressor work with a minimum of installation and operating overhead.

Note also that these Cooper-Bessemer V-angles are driving 5 compressor cylinders per unit . . . in other words, a compressor cylinder for *every* crankthrow.

Add up the advantages you stand to gain with Cooper-Bessemer V-angles—proved month-in-month-out availability, unmatched compactness, and overall operating efficiency that has yet to be equalled! Get *all* the facts. You'll see why Cooper-Bessemer V-angles are preferred units in every type of heavy-duty compressor service.

The **Cooper-Bessemer** *Corporation*

MOUNT VERNON, OHIO — GROVE CITY, PENNA.

New York City Washington, D. C. Bradford, Pa. Parkersburg, W. Va.
San Francisco Houston, Dallas, Greggton, Pampa and Odessa, Texas
Seattle, Wash. Shreveport, La. St. Louis, Mo. Los Angeles, Calif.
Caracas, Venezuela Gloucester, Mass. Tulsa, Okla. New Orleans, La.

Technical Note 149—

COMPRESSIBILITY OF RESERVOIR ROCKS

HOWARD N. HALL, STANOLIND OIL AND GAS CO., TULSA, OKLA., JUNIOR MEMBER AIME

The compressibility of reservoir rock is a factor which is generally neglected in reservoir engineering calculations. This is due in part to the fact that there is little published information on rock compressibility values for limestones and sandstones. Omission of rock compressibility is undoubtedly justified in calculations for saturated reservoirs; however, in undersaturated reservoirs,* expansion of the rock accompanying decline in the reservoir pressure may be of such magnitude as to affect materially the prediction of reservoir performance. The effect of rock compressibility will be of most importance in: (1) calculation of oil in place by pressure decline data in undersaturated volumetric reservoirs when the limits of the field are unknown or indefinite, and (2) studies of natural water drive performance. To estimate its importance in such cases, a series of laboratory tests were made to obtain usable values for reservoir rock compressibility.

The total, or effective, compressibility of any reservoir rock is a result of two separate factors, namely, expansion of the individual rock grains, as the surrounding fluid pressure de-

*A reservoir in which the pressure is in excess of the bubble point pressure, so there is no free gas and hence completely liquid saturated, is referred to as an undersaturated reservoir.

Manuscript received in the Petroleum Branch office Nov. 14, 1952.

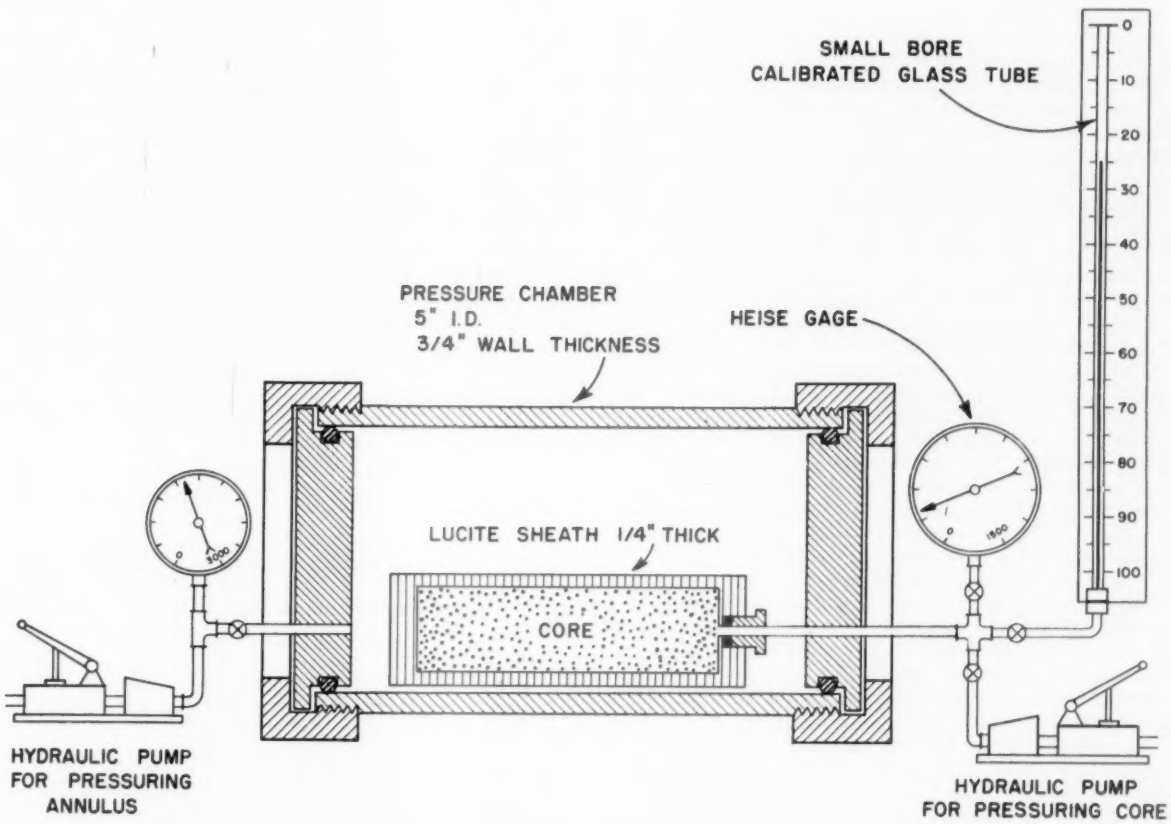


FIG. 1 — DIAGRAM OF EQUIPMENT USED FOR ROCK COMPRESSIBILITY TESTS.

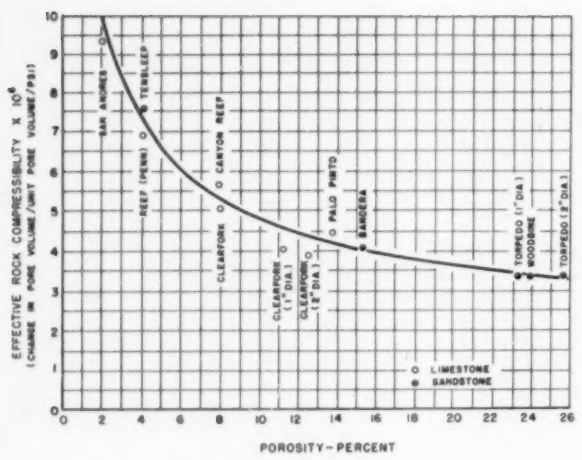


FIG. 2 — EFFECTIVE RESERVOIR ROCK COMPRESSIBILITIES.

creases, and the additional formation compaction brought about because the reservoir fluids become less effective in opposing the weight of the overburden as reservoir pressure declines. Both of these factors tend to decrease porosity. The laboratory tests were conducted in a manner that would give compressibility values representing a combination of the two factors, and would, as nearly as possible, duplicate the behavior of the rock under reservoir conditions. Fig. 1 shows a diagram of the equipment used to determine rock compressibility.

The rocks used in these tests were cores cut from producing limestone and sandstone formations. They were from 2 to 3½ in. in diameter, and 5 to 6 in. long. A core to be tested was completely surrounded by a Lucite jacket with the exception of the connection at one end to allow production of liquid during testing. To represent the effect of the overburden, a constant external hydrostatic pressure of 3,000 psig was applied to the core throughout the test. (The amount of external pressure was varied in a series of tests and no change was evidenced in the measured compressibility values.) Starting at approximately 1,500 psi static fluid pressure in the core, the core pressure was reduced by steps of 100 to 200 psi. Precise measurement of liquid production was made for each decrease in pressure. With the equipment arrangement shown in Fig. 1, the measured liquid production was a result of: (1) expansion of the system external to the core, *i.e.*, the gauge and lines leading from the core to the valve; (2) expansion of the liquid contained in the pore spaces of the rock; and (3) the actual decrease in pore space caused by rock compaction and expansion of the individual rock grains. The expansion of the system external to the core was accurately determined in separate measurements; knowing the pore space in the core and the compressibility of the fluid with which it was saturated, the expansion of liquid in the core could be calculated for any pressure drop. The true reduction in pore space due to the effective rock compressibility could then be determined by subtracting the two items above from the measured fluid production. The reduction in pore space was used to obtain the compressibility values for the rock. All compressibility values are expressed as "change in pore volume per unit pore volume per psi." To show that the Lucite jacket surrounding the core did not intrude into the core during the test, and thereby cause errors in measured compressibility values, two cores were cut down from two-in. diameter to one-in. diameter and the compressibility values redetermined. The fact that almost identical compressibility values were obtained regardless of the surface to volume ratio of the core, showed that the Lucite surrounding the core acted only as an impermeable barrier.

Fig. 2 shows the compressibility values obtained. It can be seen that there is a good correlation between rock compressibility and rock porosity. The samples tested include a wide variety of reservoir rocks, both sandstones and limestones, and cover the range of porosities existing in the majority of producing reservoirs. Because of the variety of rocks tested and the good correlation of rock compressibility with rock porosity, the correlation is considered to be applicable for obtaining usable rock compressibility values in most reservoirs. All of the compressibility values reported were measured at 95°F, and therefore, some mention should be made concerning the variation of rock compressibility with temperature. A Bureau of Mines report on rock compressibility[1] described some work done to evaluate the variation of compressibility with temperature. Tests were made at 91°F and 146°F and it was found that a very small change in compressibility occurred; however, there was no apparent relationship between temperature and compressibility. In view of this, no attempt was made in this work to obtain compressibilities at different temperatures. It should be pointed out that this correlation is not applicable to unconsolidated sands or highly fractured formations.

The Bureau of Mines publication on the compressibility of consolidated sandstones[1] gives results obtained when the formation compaction component of the total compressibility was measured on a group of consolidated sandstones. In conjunction with the total compressibility determinations shown in Fig. 2, additional tests were made to determine what part of the total compressibility values was due to formation compaction. These tests were conducted in much the same manner as those reported in the Bureau of Mines work. Fig. 3 gives a comparison of these data. The data show that there is good agreement for the formation compaction components obtained in these independent tests. The difference between the compressibility values shown in Fig. 2 and Fig. 3 represents the

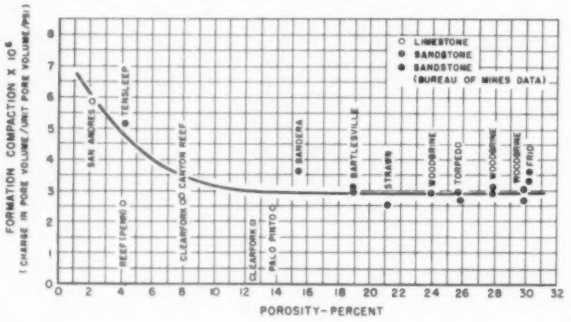


FIG. 3 — FORMATION COMPACTION COMPONENT OF TOTAL ROCK COMPRESSIBILITY.

amount of rock expansion that can be attributed to the expansion of the individual rock grains as the pressure in the surrounding fluids declines. The Bureau of Mines data on Woodbine Sand were later used in an electric analyzer study of the Woodbine aquifer,[2] and it was shown that this compressibility value in combination with the measured formation water compressibility gave an overall compressibility factor which agreed well with a compressibility factor arrived at in the analyzer study in order that actual field performance could be predicted. Previous analyzer studies[3,4] also showed that the apparent water compressibility was much higher than would be expected for the formation water, thus indicating that the compressibility of the reservoir rock is of significant importance.

From the plot of total compressibility of the reservoir *vs* porosity in Fig. 2, it is possible to estimate the change in pore space that occurs as reservoir pressure declines. The actual percentage change in pore space is small, ranging from one per cent change in pore space per 1,000 psi for the two per cent porosity sample tested to 0.33 per cent for a porosity of 25 per cent. Even though the percentage change in pore space is small, the actual reduction in pore space represents an appreciable amount when compared to the oil production to be obtained from fluid expansion in undersaturated reservoirs. Unless the change in pore space is properly taken into account, material balance calculations on an undersaturated volumetric reservoir may indicate more oil in place than is actually present and hence an overestimation of reserves. Basically, the method of estimating oil in place from pressure decline data is as follows:

$$N = \frac{n}{C_o \, \triangle P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

N = oil in place, bbl of oil at reservoir temperature and pressure*

n = oil production occurring during a certain $\triangle P$ in reservoir pressure, bbl of oil at reservoir temperature and pressure

$\triangle P$ = decline in reservoir pressure, psi

C_o = compressibility of reservoir fluid, change in volume per unit volume per psi

The values for n and $\triangle P$ are measured in field operations. Due to the change in pore space as a result of rock compressibility, all of the measured oil production, n, will not be due to fluid expansion alone. Therefore, the change in pore space of the rock must be deducted from n in order to obtain the true oil production due to fluid expansion. Taking rock compressibility into account, Equation (1) becomes:

$$N = \frac{n - NC_R \, \triangle P}{C_o \, \triangle P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where

C_R = total or effective rock compressibility expressed as change in pore volume per unit pore volume per psi

Equation (2), on rearrangement, becomes:

$$N = \frac{n}{\triangle P \, (C_o + C_R)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

If C_R and C_o are of the same order of magnitude, significant errors in reserve estimates can be made by not correcting for the effect of rock compressibility. Fig. 4 shows the importance of incorporating rock compressibilities in such material balance calculations on undersaturated reservoirs. Calculations were made to show the ratio of calculated oil in place, omitting the effect of rock compressibility, to the actual oil in place. In all cases, it was assumed that the reservoir fluid had a compressibility of 10×10^{-6} change in volume per unit volume per psi. It can be seen that the magnitude of rock compressibility is such that, if neglected, calculated values for oil in place in reservoirs covering the practical range of porosities will be from 30 to 100 per cent higher than the actual oil in place.

*For the purpose of simplification, no connate water was assumed.

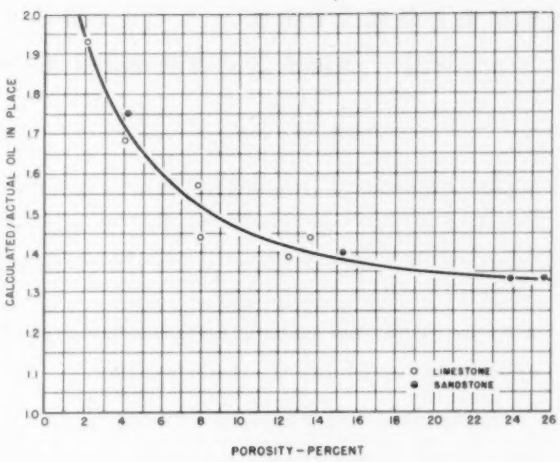


FIG. 4 — EFFECT OF ROCK COMPRESSIBILITY ON OIL IN PLACE CALCULATIONS FOR UNDERSATURATED RESERVOIRS.

ACKNOWLEDGMENTS

Appreciation is expressed to Stanolind Oil and Gas Co. for permission to present this technical note. The author is also indebted to P. L. Terwilliger, T. M. Geffen, and R. A. Morse for their aid in this study.

REFERENCES

1. Carpenter, C. B., and Spencer, G. B.: "Measurements of Compressibility of Consolidated Oil-Bearing Sandstones," Bureau of Mines RI 3540, (Oct. 1940).
2. Rumble, R. C., Spain, H. H., and Stamm, H. E., III: "A Reservoir Analyzer Study of the Woodbine Basin," *Trans.* AIME, (1951), **192**, 331.
3. Schilthius, R. J., and Hurst, W.: "Variations in Reservoir Pressure in the East Texas Field," *Trans.* AIME, (1935), **114**, 164.
4. Buckley, S. E.: "The Pressure-Production Relationship in the East Texas Field," API *Drill. and Prod. Prac.*, (1938), 140.

★ ★ ★

EVALUATING STRINGER FORMATIONS IS INEXPENSIVE WITH HYCALOGGING . . .

. . . For Hycalogging* permits you to drill straight through lenticular sands, stopping for coring and testing only in zones with known shows. Hycaloggers, using special Hycalog-developed evaulation equipment can idenify pay zones in lenticular formations without expensive losses of valuable rig time.

Behind these skilled men is the thorough training of Hycalog's planned training program and Hycalog's experience of operating over thirty logging units from Mexico to Canada.

**Hycalogging is continuous hydro-carbon logging of cuttings, mud samples, and recovered cores.*

WELL LOGGING
ON LOCATION CORE ANALYSIS
OFF LOCATION CORE ANALYSIS
SIDE WALL CORE ANALYSIS
DIAMOND CORING
DIAMOND BIT SALES

HYCALOG COMPANY

The Hycalog Company
Midland, Corpus Christi, and Houston, Texas; Jackson, Mississippi; Mount Pleasant, Michigan; Lafayette, Louisiana; Mexico City, Mexico
Main Office: First National Bank Building, Shreveport, Louisiana

Technical Note 151—

EFFECT OF QUICK-FREEZING *vs* SATURATION OF OIL WELL CORES

FRANK C. KELTON, CORE LABORATORIES, INC., DALLAS, TEX., MEMBER AIME

It is perhaps not widely realized that extraction and saturation processes carried out on oil well core samples alter the properties of these samples to varying degrees. On the other hand it is felt by some that quick-freezing of core samples increases their permeability and porosity significantly. Accordingly, laboratory tests were carried out on 49 pairs of horizontally adjacent samples in order to differentiate between the effect of quick-freezing per se on permeability and porosity of the samples, as distinguished from the effect of the identical saturation treatment on permeability and porosity of the companion samples. Also, additional field data were obtained on comparison of frozen *vs* unfrozen companion samples.

LABORATORY INVESTIGATION OF FREEZING *vs* SATURATION EFFECTS

Procedure

The samples used in these tests were two-cm cubes cut in horizontally adjacent pairs from cores from eight Gulf Coast and Mid-Continent wells, which cores had not previously been frozen. These samples were extracted with carbon tetrachloride, dried, and air permeabilities run in the conventional manner. They were then evacuated and saturated with brine of 25,000 ppm sodium chloride content, and porosities determined by gain in weight. The samples were partially desaturated by evaporation down to an average brine saturation of 68 per cent. One sample from each pair was quick-frozen by covering with dry ice after wrapping in a single layer of paper, and allowed to remain frozen for about two hours; the companion sample from each pair was not frozen. After thawing the frozen sample, all samples were immersed in tap water overnight in order to leach out most of the brine. Air permeabilities were re-run, and the samples were again saturated with brine to determine a second porosity value.

For purposes of averaging of data, the samples were grouped according to four permeability ranges, from 0 to 10, 10 to 100, 100 to 1,000, and 1,000 to 3,840 md. Average permeability and porosity changes for the frozen *vs* the unfrozen adjacent samples are shown in Table 1.

Discussion

As may be seen from Table 1, the averages of the per cent permeability increases for the quick-frozen samples ranged from 3.8 to 12.9 per cent among the four permeability groups. The average changes among the four groups of unfrozen companion samples ranged from a decrease of 0.2 per cent to an increase of 9.3 per cent. There was no particular correlation of these changes with magnitude of permeability; however, the increase for each group of frozen samples paralleled the increase for the corresponding unfrozen samples. The differences between the two sets of values are believed to be a valid indication of the effect of the quick-freezing in itself, since the treatment of the two samples in each pair was identical except for freezing.

The permeability changes which are strictly the result of the quick-freezing are shown in the sixth column of Table 1. These range from a decrease of 0.9 per cent to an increase of 4.0 per cent; the overall weighted average is 1.2 per cent, as compared to an average increase of 6.8 per cent caused by the saturation treatment of the samples not frozen.

The average porosity changes are in general smaller than the changes in permeability, and range from a decrease of 2.3 per cent to an increase of 3.3 per cent. The overall weighted average change ascribed to the quick-freezing is 1.0 per cent of porosity.

Many factors can contribute to the changes in permeability and porosity observed when subjecting cores to the simple processes used in these tests. Such are: hydration and swelling of clay, adsorption of ions, changes in surface structure and wettability, expansion and compression effects due to ice formation, shrinking and cracking, leaching of salts and colloids, displacement of particles resulting in either blocking or enlarging of pore openings. Whatever particular mechanisms are involved, however, it is apparent not only from this study but also from other investigations in the literature[1] not directly concerned with quick-freezing, that the effects produced by commonly used extraction, saturation and drying techniques may be of considerable magnitude The results of this study indicate that for the particular samples and techniques used, such effects are of the order of five to six times the effect of quick-freezing, insofar as changes in permeability are concerned.

It may be argued that these samples might not include extremely shaly material where the effect of freezing upon permeability may be much greater. However, had such material been available for these tests, it would undoubtedly have been very susceptible also to alteration by the extraction and saturation treatment used. To investigate this point further, the individual sample data were re-grouped according to the magnitude of the average per cent permeability increases for the pairs of samples, irrespective of permeability. The results

Table 1 — Permeability and Porosity Changes in Frozen Samples as Compared to Corresponding Changes in Horizontally Adjacent Samples Subjected to Identical Saturation Treatment But Not Frozen

Permeability Range, md	Number of Sample Pairs	Average Permeability, md	Average Per Cent Permeability Change		Permeability Change Due to Freezing, Per Cent	Average Porosity, Per Cent	Average Per Cent Porosity Change		Porosity Change Due to Freezing, Per Cent
			Frozen Samples	Unfrozen Samples			Frozen Samples	Unfrozen Samples	
0 - 10	15	2.7	6.1	7.0	–0.9	10.0	3.3	2.1	1.2
10 - 100	5	32	3.8	–0.2	4.0	18.4	0.0	–0.1	0.1
100 - 1,000	14	546	12.9	9.3	3.6	19.1	1.0	–0.8	1.8
1,000 - 3,840	15	1,636	6.7	6.5	0.2	21.6	–1.9	–2.3	0.4
		Weighted Averages:	8.0	6.8	1.2		0.7	–0.3	1.0

Table 2—Permeability Changes of Frozen *vs* Unfrozen Samples, Grouped by Size of Average Permeability Change

Range of Average Permeability Change	Number of Samples in Group	Average Per Cent Permeability Change		Permeability Change Due to Freezing, Per Cent
		Frozen Samples	Unfrozen Samples	
< 2%	20	0.8	−0.2	1.0
2 - 5%	10	4.5	4.1	0.4
5 - 15%	7	9.4	7.9	1.5
15- 30%	12	22.0	20.0	2.0

are shown in Table 2. It may be noted here that the largest individual permeability increase for a frozen sample was 33 per cent; the largest increase for a sample not frozen was 40 per cent. For the group of 12 sample pairs which showed the highest percentage increases, the average permeability increase for the samples not frozen was 20 per cent, whereas the difference between this and the increase for the frozen samples, *i.e.*, the incremental increase attributable to quick-freezing, was only 2.0 per cent.

Thus, from the number and variety of samples involved and the consistency in the results, it seems fairly evident that the effect of quick-freezing upon the permeability and porosity of core samples is quite small, of the order of several per cent or less, and that the larger effects ascribed by Lebeaux[2] to quick-freezing are in reality due to leaching and/or rearrangement of pore material caused by extraction and saturation techniques used.

The average increase in permeability of 16 per cent for Lebeaux' samples saturated 100 per cent with water and oil is only slightly greater than the 12.9 per cent increase shown for the 100-1,000 md group of Table 1, and one may well raise the question whether that increase would not have been almost as much on the same samples without quick-freezing, and whether some of the other samples would not have also fractured or crumbled under the same saturation and handling techniques used, without the quick-freezing.

There is reason to believe that quick-freezing of cores saturated 100 per cent with liquids may in some cases cause appreciable increases of permeability, but this saturation condition practically never occurs, if it occurs at all, in fresh cores from permeable formations.

FIELD DATA ON FROZEN *vs* UNFROZEN CORES

Procedure

As a further check on the above work, and to evaluate the results of the quick-freezing technique as it is applied in practice, core analyses were made in the conventional manner on 86 pairs of samples from six wells, four of these being from the Gulf Coast, one from West Texas and one from the Mid-Continent area. The samples comprising these pairs were always from the same foot of core and usually vertically adjacent. In the majority of cases the pieces to be used for perm plugs were taken horizontally adjacent, where the diameter of the core permitted. Half of these samples were quick-frozen at the well-site and subsequently analyzed; the other half were preserved in plastic bags, where necessary, prior to analysis by the same personnel using the same equipment as was used for the frozen cores. Complete analyses were made in nearly all cases for permeability, porosity and oil and water saturations.

The samples were grouped by permeability ranges as in the laboratory investigation described above, and averages of the data computed for each of the four groups. Since these tests are of the same nature as part of the tests reported by Wisenbaker,[3] the results shown in his Table 5 are included to make a total of 177 sample pairs, from ten wells, summarized here in Table 3

Discussion

As may be seen from Table 3, the groups and/or wells covered a fairly wide range of permeability and porosity. More variation is found between the averages for frozen and unfrozen samples than in Table 1, but this is probably a consequence of the limited number of samples and the fact that large variations may occur between the samples of each pair irrespective of freezing. Even so, the differences between permeability and porosity averages for the frozen *vs* the unfrozen samples are for the most part only a few per cent.

The overall average permeability difference between frozen and unfrozen samples is 2.7 per cent; the overall average porosity difference, 2.5 per cent. These small differences are thus of the same low order of magnitude and confirm the results found in the laboratory investigation. The overall average oil saturation obtained on frozen samples was 12.9 per cent; on unfrozen samples, 12.2 per cent. The corresponding water saturations were 40.9 and 40.5 per cent, respectively.

SUMMARY AND CONCLUSIONS

A study was made to differentiate between the permeability and porosity changes in core samples caused by quick-freezing and the permeability and porosity changes caused by identical saturation treatment without freezing, as determined on 49 pairs of horizontally adjacent samples. It was found that the permeability increase which could be ascribed to the quick-freezing amounted to 1.2 per cent, whereas the increase observed on samples not frozen averaged 6.8 per cent. No trend with permeability was discernible It was concluded that most of the changes sometimes attributed to quick-freezing are in reality due to leaching and/or rearrangement of pore material caused by extraction and saturation processes.

As an independent field check on the above conclusions, conventional core analysis data on quick-frozen samples were

Continued on Page 8, Section 2

Table 3 — A Comparison of Permeability and Porosity Averages of Samples Frozen at Well-Site *vs* Corresponding Averages for Adjacent Samples Not Frozen

Permeability Range, or Well Designation	Number of Sample Pairs	Average Permeability, md			Average Porosity, Per Cent		
		Frozen Samples	Unfrozen Samples	% Diff.	Frozen Samples	Unfrozen Samples	% Diff.
0 - 10 md	49	3.23	3.14	2.9	15.3	14.7	4.1
10 - 100 md	17	30.0	28.6	4.9	18.0	18.3	−1.6
100 - 1,000 md	15	356	339	8.0	19.2	19.3	−0.1
1,000 - 3,040 md	5	2,396	2,390	0.3	21.1	21.4	−1.4
Well A	12	125	111	12.6	26.5	24.1	10.0
Well B	22	175	167	4.6	17.5	17.2	1.7
Well C	20	22.7	22.3	1.8	18.2	17.8	2.2
Well D	37	24.9	26.0	−4.2	19.5	19.1	2.1
Total	177		Weighted Averages	2.7			2.5

JOHNSTON....

CIRCULATING VALVE

The most Positive and Versatile ever used!

Here's the newest addition to the Johnston Testing Assembly. It's the Johnston Sleeve Type Circulating Valve, for *Safer*, more *Conclusive* Drill Stem Testing. It is announced only after many hundreds of successful runs under many varying conditions in fields throughout the United States.

The Johnston Sleeve Type Circulating Valve is the answer to the Drilling Industry's demand for a circulating valve to be used for reverse circulating out the recovery on Drill Stem Tests with these qualifications:

1. **Insert at any desired point in the drilling string to allow circulation at that point.**
2. **No pump pressure applied to the top of fluid recovered on test; no pollution of fluid from test zone.**
3. **Minimum obstruction of inside of drill pipe — The Sleeve Type Circulating Valve provides a minimum of 1¾" of opening inside both 4½" and 3½" drill pipe.**
4. **Positive — No manipulation of the pipe required to operate the valve. A special type go-devil is the operating medium.**

For complete details and engineering data write for the Treatise entitled "Reverse Circulation in Drill Stem Testing."

JOHNSTON TESTERS, INC.

5702 NAVIGATION BLVD. • HOUSTON, TEXAS

FORMATION AND CASING TESTING — JOHNSTON

EXPORT DIVISION: 3035 Andrita St., Los Angeles 65, California

SERVICE BRANCHES IN ALL ACTIVE AREAS

There's a Johnston Service Representative Near You

PROFESSIONAL SERVICES

This space available only to AIME members. Rates upon request.

AMSTUTZ AND YATES, INC.
Petroleum Engineers and Geologists
Estimates of Oil & Gas Reserves
Property Valuations, Reservoir Analyses
Geologic Investigations
406 KFH BLDG., WICHITA 2, KANS.

E. A. WAHLSTROM BURTON ATKINSON
PETROLEUM CONSULTANTS
Engineering - Geology
MIDLAND, TEXAS
130 Central Building Phone 4-8037

BERGER AND PISHNY
Consulting Geologists and Engineers
901 Commercial Standard Bldg.
Fort Worth 2, Texas
Walter R. Berger Chas. H. Pishny

BRADLEY, CRICHTON and ASSOCIATES
PETROLEUM CONSULTANTS
Geology, Engineering and Management
Robert J. Bradley W. Ray Staples
John A. Crichton R. Wayne Russell
Mac D. Oliver H. Eugene Wright
Virgil B. Harris Bernard J. Esunas
Otis T. Griffin Walter A. Tynes
Clyde C. Harter, Jr. Kenneth C. English
903 Employers Insurance Building
Dallas, Texas RAndolph-2241

JOHN G. CAMPBELL
Consulting and Petroleum Chemist
Podbielniak and Charcoal Analyses
Waters - Oil Field Brines
Field Sampling
CORPUS CHRISTI INGLESIDE, TEXAS

CHEMICAL & GEOLOGICAL LABORATORIES
Consultants - Investigations - Evaluations
James G. Crawford.....Chemical Engineer
H. E. Summerford.....Petroleum Geologist
F. Raymond Wheeler....Petroleum Engineer
P. O. BOX 279 CASPER, WYOMING

CRUTCHFIELD AND PRUETT
CONSULTING PETROLEUM ENGINEERS
. Wilson Tower
CORPUS CHRISTI, TEXAS
John W. Crutchfield *Horton T. Pruett*

DENTON-SPENCER COMPANY, LTD.
PETROLEUM ENGINEERS AND GEOLOGISTS
PHOTOGEOLOGISTS PHOTOGRAMMETRISTS
Barron Building Calgary, Alberta

EARLOUGHER ENGINEERING
Petroleum Consultants - Core Analyses
Specializing in Secondary Recovery
Investigations - Appraisals - Operations
3316 East 21st St.
TULSA 5, OKLAHOMA
Phone: 9-6345

EASTON & SACRE
Consulting Petroleum Engineers
1660 Oak Street
BAKERSFIELD, CALIFORNIA
Phone 2-3934

FITTING & JONES
Engineering and Geological Consultants
Petroleum Natural Gas
Box 1637
223 S. Big Spring St. Midland, Texas

ROBERT D. FITTING
Petroleum Consultant
Engineering and Geology
MIDLAND, TEXAS
202 West Building Phone: 4-4922

MICHEL T. HALBOUTY
CONSULTING GEOLOGIST
AND PETROLEUM ENGINEER
Shell Building
Houston 2, Texas Phone PR-6376

RICHARD V. HUGHES
Secondary Recovery of Oil
Mining Building Stanford University
Stanford, California

PETROLEUM CONSULTANTS
Engineering and Geology
E. O. Bennett James O. Lewis
D. G. Hawthorn William Hurst
M. D. Hodges
1552 Esperson Bldg. Houston, Texas

KELLER & PETERSON
Petroleum Consultants
Reserve Estimates Property Appraisals
Petroleum and Geological Engineering
Reservoir Analysis
MIDLAND, TEXAS
P. O. Box 222 Phone 4-6181
W. O. Keller L. F. Peterson

JAMES A. LEWIS ENGINEERING, INC.
Petroleum Reservoir Analysts
Dallas, Texas Evansville, Indiana
Robinson, Illinois
Owensboro, Kentucky Winchester, Kentucky

LLOYD, PENN & HILLS
E. Russell Lloyd John M. Hills
William Y. Penn T. F. Harriss
John S. LeSassier John E. Turner
Geologists — Consultants — Appraisers
21 PERMIAN BUILDING
MIDLAND, TEXAS

OILFIELD SERVICE COMPANY
Electric Logs — Gamma Ray — Caliper
Water Input Profiles
Specializing in Secondary Recovery
PAWHUSKA, OKLAHOMA

OILFIELD RESEARCH
Core Analysis — Evaluation
Development of Water Flood Projects
Operation of Water Flood Projects
EVANSVILLE, INDIANA
1907 Division Street
Phones: 6-5591 and 6-4482

ERNEST K. PARKS
CONSULTING PETROLEUM ENGINEER
Planning, Direction and Examination of
Oilfield Operations, Estimates of Oil and
Gas Reserves, Oil Property Valuation
151 N. CANYON VIEW, LOS ANGELES 49, CALIF.
Telephone: VanDyke 4659

HARRY H. POWER
PETROLEUM AND VALUATION ENGINEER
Box 1542 University Station
Austin, Texas

E. E. REHN
Consulting Petroleum Geologist
Oil Exploration
Wood Building, 624 Locust Street
EVANSVILLE, INDIANA

FRED E. SIMMONS, JR.
Geology and Petroleum Engineering
Louisiana Gulf Coast
Raymond 9408 807 Hibernia Bank Bldg.
New Orleans, Lousiana

SOL SMITH
CONSULTING ENGINEER
PETROLEUM AND NATURAL GAS
Reserves Deliverability
Oil and Gas Proration
913 BROWN BUILDING
AUSTIN, TEXAS PHONE: 89498

WM. H. SPICE, JR.
Consulting Geologist
2101-03 Alamo National Building
SAN ANTONIO 5, TEXAS

TRAFFORD & ASSOCIATES
Geological, Petroleum Engineering and
Management Consultants
E. Trafford Wales Hotel Bldg. Phones
R. Pat 10th Floor 61212
P. Klaui Calgary, Alberta 61224
63132

HAROLD VANCE
CONSULTING PETROLEUM ENGINEER
Pet. Engr. Dept. A & M College
College Station, Texas

PROGRAM

of Petroleum Branch Activities

1953 ANNUAL MEETING

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

Hotel Statler • February 14 - 19 • Los Angeles

HOWARD C. PYLE, *General Chairman*
Petroleum Branch Activities

Saturday, February 14

10:00 a.m. — Council of Section Delegates Meeting

Sunday, February 15

2:00 p.m. — AIME Board of Directors Meeting

Monday, February 16

8:00 a.m. — Registration

9:00 a.m. — Petroleum Branch Executive Committee Meeting

12:15 p.m. — AIME Welcoming Luncheon — GOVERNOR DAN THORNTON of Colorado, speaker

2:00 p.m.-5:00 p.m.—World Oil and Gas Developments in 1952

R. B. GILMORE, *Presiding*

Annual production review session, giving the highlights of world-wide oil and gas developments and production during 1952.

Presented by the 1952 Production Review Committee:
E. W. Berlin, Chairman
R. B. Gilmore, Domestic Vice-Chairman
Alexander H. Chapman, Foreign Vice-Chairman

Committee Members:
Alfred H. Bell
Raymond M. Larsen
Lawrence W. Chasteen
Milton Williams

7:30 p.m. — AIME Stag Smoker

Tuesday, February 17

9:00 a.m.-12:00 m. — Technical Session

F. L. WADSWORTH and M. E. LOY, *Associate Chairmen*

9:00 a.m. — 258-G: *High-Temperature Gelation of Drilling Fluids*, by T. E. Watkins and M. D. Nelson, Magnolia Petroleum Co.

10:00 a.m. — 259-G: *Entrapment of Petroleum Under Hydrodynamic Conditions*, by M. King Hubbert, Shell Oil Co.

2:00 p.m.-5:00 p.m. — Symposium on Valuation of Oil and Gas Properties

KENNETH E. HILL and EVERETT G. TROSTEL, *Associate Chairmen*

Introductory Remarks, Paul Paine, Consultant, Los Angeles.

Valuation of Oil Properties, by Dean Sheldon, Consultant, Los Angeles.

Valuation of Natural Gas Properties, by Ralph E. Davis, Consultant, Houston.

Valuation of Oil and Gas Properties for Loan Purposes, by Lyon F. Terry, Chase National Bank.

Valuation in Petroleum Security Analysis, by Edwin L. Kennedy, Lehman Brothers.

Discussion — Panel members and audience.

7:00 p.m. — Petroleum Branch Dinner

Wednesday, February 18

9:30 a.m.-12 m. — Technical Session

C. R. DODSON and KEMP E. BARLEY, *Associate Chairmen*

260-G: *Use of Automatic Free Piston in Oil Well Production Problems*, by E. D. McMurry, Garrett Oil Tools, Inc.

261-G: *Capillary Desaturation in Porous Glass Bead Systems*, by John C. Calhoun and Frank T. Bethel, Pennsylvania State College.

262-G: *Well Spacing and Reservoir Performance — Spraberry Trend Area*, by Lincoln F. Elkins, Sohio Petroleum Co.

1:30 p.m.-5:00 p.m. — Technical Session

J. SHANNON BAKER and A. H. BELL, *Associate Chairmen*

263-G: *Recent Laboratory Investigations of Water Flooding in California*, by Norris Johnston and N. van Wingen, Petroleum Technologists, Inc.

264-G: *The Effect of Viscosity Ratio on Relative Permeability*, by A. S. Odeh and S. T. Yuster, University of California at Los Angeles.

265-G: *Steady-State Flow of Gas Through Capillary Tubes*, by George C. Wallick, Magnolia Petroleum Co.

7:00 p.m. — AIME Annual Banquet and President's Reception

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE AIME ANNUAL MEETING

258-G

High-Temperature Gelation of Drilling Fluids

T. E. Watkins and **M. D. Nelson**

This paper summarizes the manifestations of high-temperature gelation, the causes of high-temperature gelation, and the retarding effect on this condition by a number of chemical compounds in drilling fluids. Equipment and methods developed for laboratory and field pilot testing are described. Analysis and utilization of high-temperature test data in completion operations are discussed. A nomograph based in part on laboratory-derived information is presented for the rapid calculation of shear strength characteristics of drilling fluid after being subjected to down-hole conditions, and for predicting whether certain bore-hole operations could be successfully carried out under such conditions.

259-G

Entrapment of Petroleum Under Hydrodynamic Conditions

M. King Hubbert, Shell Oil Co., Houston, Tex.

The anticlinal or so-called "gravitational" theory, despite its effectiveness as a basis for petroleum exploration, represents but a special case of oil and gas accumulation, and is valid only when the associated ground water is in hydrostatic equilibrium. Since this need not be the case a more general formulation, valid for both hydrostatic and hydrodynamic conditions, is required. Oil and gas possess energy with respect to their positions and environment which, when referred to unit mass, may be termed the potential at any given point of the fluid considered. When the potential of a specified fluid in a region of underground space is not constant, an unbalanced force will act upon the fluid, tending to drive it in the direction in which its potential decreases. Hence oil and gas in a dispersed state underground tend to migrate from regions of higher to those of lower energy levels, and come ultimately to rest in positions which constitute traps, where their potentials assume locally minimum or least values.

262-G

Reservoir Performance and Well Spacing Spraberry Trend Field of West Texas

Lincoln F. Elkins, Sohio Petroleum Co., Oklahoma City, Okla.

The Spraberry Trend Field of West Texas, having 2,182 wells and 38,230,000 bbl cumulative production as of Nov. 1, 1952, promises to extend over an area in excess of 400,000 acres. Pay section of this unique reservoir consists primarily of two 15-ft sand zones in a 1,000-ft thick section of shales, siltstones, and limestones. An interconnected system of vertical fractures, observed in cores, permits recovery of oil from these sands which have permeability less than one md. Reduced pressures at time of completion observed in later drilled wells are reproduced within ±30 psi in 60 per cent of cases of a six mile long test area by compressible fluid flow theory using factors for porosity, connate water saturation, fluid and rock compressibilities and average fracture opening as measured in cores.

263-G

Recent Laboratory Investigations of Water Flooding in California

Norris Johnston and **N. van Wingen,** Petroleum Technologists, Inc., Los Angeles, Calif.

Laboratory flood pot testing of California sands has progressed to a considerable extent in the past 18 months. Flood evaluations have been carried out on over 200 large core samples. Many of these were heavy oil sands of high permeability, completely unconsolidated nature. The oil frequently formed a bank, though some of the oil was recovered in the subordinate phase of the flood, by viscous drag. Flood pot recoveries as high as 1,300 bbl/acre ft have been recorded. Reservoir analysis suggests a conformance factor of 0.4 to reduce laboratory recovery to probable field practice. Oils with viscosities up to 1,700 cp have been successfully handled in flood pot evaluations. The shallow, loose sands are not well adapted to the application of high pressures to offset the high viscosities.

264-G

The Effect of Viscosity Ratio on Relative Permeability

A. S. Odeh and **S. T. Yuster,** University of Southern California at Los Angeles

A study was made of the effect of viscosity ratio on relative permeability in an oil-water system in which the wetting phase saturations(aqueous) were at the irreducible minimum. The viscosity range of the aqueous phase was from 0.87 to 6.37 cp and that of the oil phase was from 0.50 to 164 cp. Nine cores were used in the study, of which six were from California fields and three were of sintered pyrex glass. A total of 90 relative permeability tests were made on these cores. The results indicated that relative permeability is a function of viscosity ratio and further that the fractional relative permeability may be greater than unity.

265-G

Steady-State Flow of Gas Through Glass Capillary Tubes

George C. Wallick, Magnolia Petroleum Co., Field Research Laboratories, Dallas, Tex.

This paper describes experimental procedures for the calibration of capillary tubes to be employed as comparison standards in gas flow rate measurements and considers a number of the factors which must be taken into account in a complete theoretical description of the flow of a gas through a capillary. In the calibration at average gas pressures of 1.0, 2.5, 4.0, and 6.0 atmospheres of seven capillaries with radii increasing from 0.004 cm to 0.070 cm, several types of flow were observed. The flow through the three smallest capillaries was viscous, following the classical Poiseuille flow equation. The flow through each of two capillaries of intermediate radii was also viscous, but the observed flow rate was less than that predicted by the Poiseuille equation. This difference was found to increase with increasing average pressure and/or increasing differential pressure. It is shown that this type of flow may be described by a modified form of the Poiseuille equation with the classical correction for the kinetic energy effect. The flow through the two largest capillaries was found to become turbulent for average pressure greater than one atmosphere.

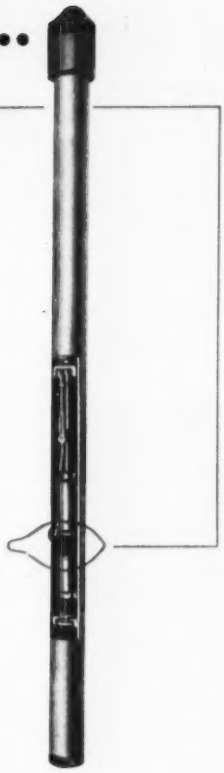
HALLIBURTON

TESTING SERVICE

big bonus of testing...

BOURDON TUBE

Gives Greater Accuracy In Pressure Recording At No Extra Cost!



MAKES HALLIBURTON BEST FOR YOUR DRILL STEM TEST!

No ifs or buts about the B. T. Bomb. It's the most precise pressure recording device, bar none. And it costs you nothing more.

This Bourdon Tube goes down the hole along with the Standard PRD. You get *both* records right after the test. Exacting engineers and geologists *want* both records – for the greater accuracy of the B. T. can make a whale of a difference.

Absence of packing glands in the Bourdon Tube make it *supersensitive* to the slightest variations of pressure changes. It is run with a blank chart made from sheet copper specially treated to withstand high temperatures of present day deep drilling. Clocks used to drive the B. T. are specially designed to withstand shock and high temperatures.

It is supplied in pressure ratings from 5,000 psi. to 15,000 psi. The base line or zero pressure line is drawn after the instrument is assembled. Recordings are measured in inches of deflection and converted to pressure from a calibration curve. The pressure readings are corrected to the bottom hole temperature of the well tested.

Halliburton's Testing Specialists are equipped to make field readings of the chart right after the test. But these readings are checked at the laboratory on a Micrometer Optical Chart Reader. You get a complete data sheet plus a *photographic* copy of the chart – leaving no chance for human error.

This big bonus of testing accuracy is yours at no extra cost. Make sure you get it on your next test. The Bourdon Tube is exclusive with Halliburton, so phone your nearby Halliburton Tester. Halliburton Oil Well Cementing Company, Duncan, Oklahoma.

MORE REASONS WHY HALLIBURTON'S BEST!

★ *YOU GET BENEFITS OF BIG RESEARCH*

★ *YOU GET MILLION-JOB EXPERIENCE*

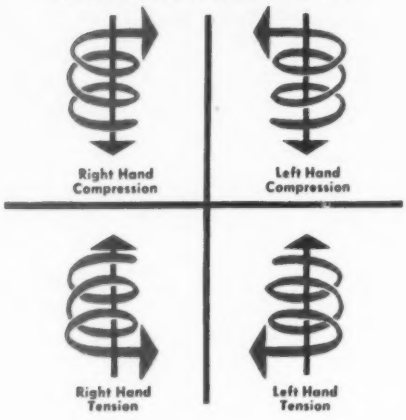
★ *YOUR TEST CAN START MINUTES FROM NOW*

HALLIBURTON

YEARS AHEAD IN DRILL STEM TESTING!

A simple, positive way to REMOVE STUCK TUBING STRINGS FROM YOUR PRODUCING WELLS

4 TYPES TO MEET EVERY PRODUCTION REQUIREMENT



Why run the risk of costly salvage operations every time stuck packers, sanding conditions or similar difficulties jeopardize recovery of your tubing string, when it costs so little to insure recovery by using Baash-Ross Production Safety Joints?

A Baash-Ross Production Safety Joint placed in your tubing string provides a positive means of freeing the string at the point where the Safety Joint is installed, thus permitting important savings to be made in production operations. For example . . .

▶ Where production packers are used, a Safety Joint should be installed above the packer to permit positive and complete release of the tubing string should the packer become stuck.

▶ Where sanding conditions exist, one or more Baash-Ross Production Safety Joints should be installed in the tubing string to permit selective release and maximum recovery.

▶ Where it may be desirable to change production methods in a well, a Baash-Ross Production Safety Joint should be installed in the tubing string to permit such changes to be made quickly and easily without disturbing the packer.

Baash-Ross Production Safety Joints are simple in design, positive in operation and low in cost. They are provided with a unique locking lug that permits heavy rotational loads to be transmitted through the Joint without loosening it—yet disengagement can be quickly made whenever desired by merely following a simple sequence of operations. A choice of *four* different releasing actions is available—either *left* or *right* hand rotation, combined with either *raising* or *lowering* the production string—thus providing the exact releasing action best suited to each production hook-up.

LEAK-PROOF SEAL . . . FULL OPENING PASSAGE

Note how the Baash-Ross Production Safety Joint is packed off top and bottom with self-sealing "O" rings to permit circulation without leakage. Also, the Joint is full-opening so that rods, tools and clean-out equipment can be passed without difficulty. In fact, the Joint has the same internal and external diameters as the production string itself. Anything that passes through the tubing string will pass through the Joint . . . and the Joint itself will pass through anything the tubing couplings will pass through — an important consideration when used with certain suspensions.

QUICK POSITIVE RELEASE

Here's how the Baash-Ross Production Safety Joint operates to protect your tubing strings. The Joint consists essentially of a box and pin releasing thread (either right or left hand, as ordered) that is packed off top and bottom with self-sealing "O" rings. In the upper portion of the pin thread, two vertical lugs are machined into the body, and these lugs mate with a corresponding lug machined into the box portion.

The releasing threads are cut with a loose fit—that is, when the Joint is made up, the two portions can move a short distance longitudinally with respect to one another without affecting the vertical alignment of the Joint. This movement permits the mating lugs to lock and unlock as one portion of the Joint is moved with respect to the other portion—and the design of the lugs determines whether the Joint unlocks in tension or in compression. A shear pin is also provided that permits longitudinal movement of the Joint, but prevents premature rotational release.

Basically, the releasing action consists of first unlocking the lugs by lowering (or raising) the string—then rotating the string in the proper releasing direction (either right or left) to sever the shear pin and unscrew the Joint. Only by first moving the string in the proper vertical direction, then rotating it in the correct releasing direction, can the Joint be disengaged—and by properly selecting the releasing action, other tools below can be set and released without risk of disengaging the Joint.

A Size For Every Production Need

Baash-Ross Production Safety Joints are made of heat-treated alloy steel and are available in all four releasing actions to fit all sizes and types of API Tubing. So no matter what the nature of your particular production operations, you can protect against costly salvage jobs by placing one of these efficient Joints on every tubing string.

Available through leading Supply Stores

Baash-Ross

TOOL COMPANY *Our 33rd year*

GENERAL OFFICES: 5512 SO. BOYLE AVE., LOS ANGELES 58
OKLAHOMA CITY 9 • HOUSTON 20 • ODESSA • CASPER
Export Offices: 11 W. 42nd St., New York 36

Petroleum Branch Affairs

. . . as interpreted by JOE B. ALFORD
Executive Secretary, Petroleum Branch

The discontinuance of Edward H. Robie's column, "The Drift of Things," brought keen regret to many members who have read it and enjoyed it for years. Several have told me that they always turned to "the Drift" first when reading the magazine, and invariably their manner of making this statement revealed that the column was one of their personal links with the Institute. Members felt this way toward the column because it reported and interpreted the human side of engineering. As such it made a real contribution to the Insttiute and profession, and I feel that members will join me in expressing appreciation to Secretary Robie for that contribution.

Some have asked me to continue in Mr. Robie's place. I could not bring his wit and wisdom to the column, and also I feel that such a respected title as "the Drift" is the author's property which should be allowed to demise at his will. Hence, I will not endeavor to continue Mr. Robie's fine work, but I will endeavor to report and interpret matters of interest concerning the Institute and Branch through the medium of this column.

* * *

Decision on Publishing Program

After extended study and discussion by the Executive Committee and Branch staff, the Executive Committee recently made a basic decision on a future publishing program for the JOURNAL OF PETROLEUM TECHNOLOGY which may continue for years, and which will definitely affect every member. The decision concerned the future development of advertising in the magazine and the means of accomplishing the selected objective.

There are two fundamental schools of thought on how far we should go in developing advertising in the JOURNAL OF PETROLEUM TECHNOLOGY:

1. We are not commercial publishers, and we should develop advertising only to where it pays for publication of the magazine;
2. We should develop advertising to a reasonable maximum and let the membership benefit from the profits.

In studying the problem, the first concept was labelled Plan One, and the second was labelled Plan Two. Plan One could be accomplished by developing the advertising to about $100,000 gross income per year, and if Plan Two were adopted a reasonable maximum advertising gross might be $160,000 per year.

The advertising gross increased from about $22,000 in 1950, to $38,000 in 1951, and to $54,000 in 1952. We expect that this rate of increase will begin to decline during the next year or so unless concentrated effort is devoted to advertising promotion. The solution would be an increased staff to sell advertising, and if Plan Two were followed this increase should be effected now in order to lay the foundation for future development. The essential elements of the problem facing the Branch, then, was to decide what long-range program should be adopted in publishing the magazine, and what staff should be employed to execute it.

Up to this point one person has functioned as both editor and advertising manager for the magazine. Advertising has been sold through agents called publisher's representatives who are compensated only by commissions on what they sell. It is reasonable to expect that the objective of Plan One ($100,000 gross per year) can be reached within perhaps five years by continuing this arrangement. At that point, all costs of printing, distribution, salaries, office, and travel for the magazine will be paid for entirely from advertising.

To develop the gross income to a probable maximum limit of $160,000 per year under Plan Two would necessitate an expanded staff for both the editorial and advertising sides. Particularly, it would call for the employment of a full-time advertising manager within the immediate future in order to establish a foundation now on which to build later sales efforts.

This problem itself had some thorny sides, and we executed an intensive staff study of it in August and September. The problem was made more complex, however, with a proposal in late September from an outside commercial publisher in the petroleum industry. The essence of this proposal was that the outside publisher would (1) assume all of the costs of producing and distributing the magazine; (2) sell the advertising, do all billing for it and receive the advertising income; and (3) split the income on some basis with the Petroleum Branch. The attractive feature of this proposal was that the Branch would be guaranteed a magazine free of charge during the term of a contract (presumably 10 years), regardless of economic conditions. Also, the business of publishing a magazine would be placed out on contract, which would free the Branch to devote its energies to the primary function of being a professional society. The proposal had its undesirable aspects, in that the copyright name JOURNAL OF PETROLEUM TECHNOLOGY would go to the outside publisher in the event of default or withdrawal from the contract by the Branch, and the commercial aspects of publishing would be emphasized more than they would under AIME publication.

The Branch Executive Committee considered all of the proposed programs for several hours during the Houston meeting, and subsequent to that a number of informal meetings were held in various places in an effort to reach the right conclusion. Finally, the Executive Committee held a special called meeting in Dallas on Nov. 24, 1952, and made the following decisions:

1. The outside publisher's proposal did not provide for enough money to be returned to the Petroleum Branch to make it attractive with the undesirable features involved;
2. The Branch is fundamentally interested in having only a self-sustaining publication, and that we should not become too deeply involved in the business of publishing, so Plan One was adopted for an indefinite period of future operation.

Subsequent to this meeting, Richard C. Wipperman was appointed our representative for advertising sales in the Southwest, West, and Midwest. He will be compensated on a commission basis for advertising sold, but will devote the major part of his time to the TECHNOLOGY during the next year, and will carry the title of advertising manager. Jess E. Adkins will continue as editor, but will devote his major attention to the editorial side of the magazine. Advertising outlook for 1953 is good at present, and the budget has been set at $65,000 gross income.

The Executive Committee has really earned a vote of thanks from the membership in reaching the decision on this problem. ★ ★ ★

TEXAS A&M PETROLEUM CLUB members heard a talk by A. E. Burgin, oil land broker of Fort Worth, at a recent meeting. L to R, above, are E. T. Guerrero, club sponsor; Burgin; Harold Vance, head of Oil and Gas Division, Second National Bank, Houston; and Denton Wieland, club president.

How Many of Your Staff Are Going To the Annual Meeting?

By Edward H. Robie
Secretary, AIME

In our recent visits to some 15 Local Sections we have tried to impress on members the value of attendance at Institute meetings, specifically the Annual Meeting this year in Los Angeles where some 2,500 professional men will forgather. In many instances, particularly with the younger men, the response has been a rather wistful smile with the remark that "I certainly would like to be there." They want like the devil to go, and feel they would get a great deal out of it, but they are pretty sure they will not be allowed to go. They all work for someone else, and it is the top brass that all too often takes such trips.

We recall the first job that we ever had in the mining industry. Not long after we were employed — three years to be exact — we were sent, not to an AIME meeting, but on a field trip of several weeks to investigate operating practice of other companies. The aim was the same as attendance at a meeting, but the trip was more costly in time and money. Its purpose was primarily to learn things that would save our employer money, and to make us a more valuable employe to them. Incidentally our wife was sent along with us, and it served as our honeymoon. We feel that our later report to the company was worth what it cost, but we may be prejudiced. Certainly, the company thereby secured an enthusiasm in our work, and a staunch friend for years to come.

Employers, we believe, should give serious thought to which members of their staffs should attend the Los Angeles meeting. Other factors being reasonably equal, AIME members should certainly be preferred to nonmembers, else the members will naturally believe that their membership counts nothing. The trip should be looked on as an investment, and those selected to go should be those that have shown by their work that they are most likely to profit by the contact with others in their line of work. They should be required to make some kind of a report of what they have learned, the people they have met, and the ideas they have developed. But not only is the return to the employer the increased knowledge attained by the employe, but the great improvement likely in his morale. He will be a better friend of the company, more satisfied with his job.

The less liberal employer will surely give permission to attend the meeting, without paying expenses. Even this would be deeply appreciated by many young men, especially those not too distant from Los Angeles. No operation is likely to suffer much because of anybody's absence for a week. Operations continue even when one is ill, or on vacation. A more liberal attitude is to pay expenses as well as to accord permission. And if an employer wants to make a still greater investment, with higher dividends, he will send both the man and his wife. More and more companies are doing this.

It is just as important to keep the human tool sharp and bright as it is the machine. ★ ★ ★

Texas A&M Club Elects Juniors

Reported by F. M. Rozelle

The Texas A&M Petroleum Club, student affiliate, held its initial meeting of the year on the evening of Sept. 17, 1952, in the petroleum engineering lecture room. At this meeting the senior officers, President Denton R. Wieland, Vice-President Bob Hubbel, and Publicity Agent F. McQueen Rozelle were introduced to the club. The following Junior officers were elected: John Neal, secretary; Henry Ince, treasurer; and John Tracy, Junior representative to the Engineer's Council. Instructor E. T. Guerrero was unanimously chosen as faculty sponsor.

The club was well represented at the Petroleum Branch Fall Meeting which was held in Houston Oct. 1, 2 and 3. Tom Bailey, Royce Robin, Aaron Campbell, Spud Mergele, Glenn Rader, Al Sheppard, Bob Hubbel, Jerry Eubanks and Denton Wieland attended and reported a fine time.

A social gathering was held on the evening of November 5 for the members. With the help of plenty of barbecue and refreshments, everyone thoroughly enjoyed himself.

The interest that the Junior members are showing is evident and gratifying, as recent figures show that they comprise almost one-half of the club's AIME student membership.

A. E. Burgin, oil land broker from Fort Worth, Tex., was the guest speaker on Nov. 19, 1952. His talk, based on his personal experiences, was on the topic, "The Oil Land Broker and His Activities" and more than 100 members attended.

D. V. Carter, chief petroleum engineer of the Magnolia Petroleum Co., was to discuss "What the Industry Expects from the Petroleum Engineer and What the Petroleum Engineer Can Expect from the Industry" at the meeting on Jan. 7. ★ ★ ★

Common Stock Investments Approved by AIME Board

At the Board meeting on Nov. 19, consideration was given to the wisdom of investing an increased portion of AIME funds in common stocks rather than bonds or preferred stocks. Permission was voted to allow the investment committee to invest up to 50 per cent of Institute funds in common stocks except where special conditions or limitations exist, as in certain specific funds. The instruction was permissive and not directive. ★ ★ ★

Employment Notices

The JOURNAL will post notices of men and jobs available. Companies and AIME members are invited to use this space, for which there is no charge. Except as noted below, address replies to: Code (appropriate number), JOURNAL OF PETROLEUM TECHNOLOGY, 800 Fidelity Union Bldg., Dallas 1. Show return address on envelope. These replies will be forwarded unopened and no fees are involved.

Replies to the positions coded Y7416 (a), Y7547, Y7958(b) and Y8035 below should be addressed to: Engineering Societies Personnel Service, 8 West 40th St., New York 18, N. Y. The ESPS, on whose behalf these notices are published here, collects a fee from applicants actually placed.

PERSONNEL

♦ Geologist, MS, age 34, 12 years' varied experience in U. S., Canada, Europe, South America, Africa. Surface and subsurface background. Desires foreign assignment in supervisory capacity. Code 178.

♦ Graduate petroleum engineer, 10 years' varied administrative, operational and engineering experience with major. Now in responsible supervisory position. Interested in change to responsible position with smaller firm or independent. Code 179.

♦ Graduate petroleum engineer with two years' training in reservoir engineering, including some PVT studies. Experience in gas-distillate well production testing, reserve estimation and valuation. Presently employed with small independent. Prefer location in Houston, Tex. Married, age 25. All offers acknowledged. Code 180.

♦ Petroleum engineer, 1952 graduate of Oklahoma University, age 33, desires position with progressive independent interested in secondary recovery. Presently employed. Code 181.

♦ Reservoir engineer, graduate with five years' experience combined with research including PVT, secondary recovery, consulting, oil and gas property evaluation, presentation of data before Federal Power Commission and Railroad Commission. Married, age 28, presently employed in supervisory capacity in Texas. All offers acknowledged. Code 182.

POSITIONS

♦ Continental Oil Co. has openings for several reservoir engineers at Ponca City, Okla. Work will consist of calculating and maintaining records of company reserves, evaluations, secondary recovery applications, and reservoir studies. Prefer men 25-35 with some experience. Excellent working and recreation facilities. Salary commensurate with experience and education. Write direct to W. W. Wilson, Asst. Chief Reservoir Engineer, P. O. Box 1267, Ponca City, Okla.

♦ Wanted in Oklahoma by independent operator an experienced production man for completion and workover. Must be willing and able to stay on job. Give personal and job data, also salary required, in reply. Code 544.

♦ Young chemical engineer, physicist, or petroleum engineer, with PhD degree to direct research work in petroleum production engineering and teach cycling, pressure maintenance and related subjects. Give complete personal and educational history, enclose photograph and salary required. Apply to Department of Mining and Petroleum Engineering, The Ohio State University, Lord Hall, Columbus 10, Ohio.

♦ Mechanical engineer with interest or experience in automotive field, to do test work on synthetic lubricants and anti-freeze compounds for large research laboratory. Report writing ability important. Salary, $4,200-$5,400 a year depending on qualifications. Location, western New York State. Y7416 (a).

♦ Professor, preferably with PhD degree, to take charge of courses in the field of petroleum production engineering and also do some research work along the line of reservoir engineering. Location, Southwest. Y7547.

♦ Engineering draftsman, 30-45, mechanical or chemical graduate, with substantial experience in petroleum refinery or other process industry affording thorough knowledge of equipment standards and standard practices in designing and drafting of equipment, plus experience in designing, drafting and making engineering calculations for a variety of problems. Act as leader man of major new refinery layouts or revisions of existing layouts; prepare estimate sketches and data, engineering flow diagrams, etc. Check drawings and design of jobs. Salary, $6,050 a year. Location, Pennsylvania. Y7958(b).

♦ Technical sales engineer for petroleum products sales in Bombay, India. Should have eight to ten years' experience in industrial sales, preferably chemical or petroleum. Salary open. Twenty-five per cent premium for overseas service plus living and housing allowance. Y8035. ★ ★ ★

ENGINE RESEARCH SPECIALIST

To be in complete charge of laboratory for testing and developing engine fuels and engine lubricating oils for large oil company in Scandinavia. Applicant must have a thorough theoretical education as a mechanical engineer and practical experience of gasoline and diesel engines as well as in testing engine lubricants and fuels. He must also be familiar with additives for lubricating oils. Salary open. Lodgings can be arranged. Applications covering education, experience, references and salary desired to Code 545-A.

Speakers Announced for Oil and Gas Law Institute

A number of outstanding speakers will present papers at the Fourth Annual institute on the law of oil and gas and taxation to be held January 21-23 at the Southwestern Legal Foundation in cooperation with the Southern Methodist University School of Law in Dallas, Tex.

Among the speakers familiar to the oil industry will be Lewis W. MacNaughton of DeGolyer and MacNaughton; Frank J. Scurlock of Turner, Rodgers, Winn, Scurlock and Terry; Nelson Jones of Humble Oil and Refining Co.; Martin G. Miller of John R. Butler and Co.; Charles I. Francis; Morris C. McGowen of United Gas Corp.; Ben R. Howell of Jones, Hardie, Grambling and Howell; George Sierkin of Foulston, Siefkin, Schoeppel, Bartlett and Powers; Charles P. McKean of The California Co.; Homer Lindsey Bruce; John G. McDonald of Imperial Oil Co., Ltd.; John B. Dunlap of the Bureau of Internal Revenue; Rowsell Magill; Benjamin L. Bird and Felix Atwood. ★

Southern Sierra Subsection Approved by AIME Board

Basil Kantzer, chairman of the Southern California Section, requested the Board's permission for establishment of the Southern Sierra Subsection of the Southern California Section, which was granted at the Nov. 19 Board meeting. The San Francisco Section had indicated its willingness to release all of Mono and Inyo counties and that part of Kern County east of the Sierras north of Mojave, and that part of San Bernardino County north and northeast of Highway 466. ★ ★ ★

Proposed for Membership, Petroleum Branch

Total AIME membership on Oct. 31, 1952, was 18,333; in addition 1,697 Student Associates were enrolled.

ADMISSIONS COMMITTEE

T. D. Jones, Chairman; Thomas G. Moore, Vice-Chairman; Harold S. Bell, F. W. Hanson, R. H. Chadwick, T. W. Nelson, J. H. Scaff, John T. Sherman, A. C. Brinker, Ivan Given, C. A. R. Lambly, G. P. Lutjen, E. A. Prentis, and C. Leslie Rice, Jr.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

ARKANSAS

Camp Chaffee — Eristoff, Constantine Sipamon (C/S-S-J).
Magnolia — Pearson, Ralph Eric (J).

CALIFORNIA

Bakersfield — Randall, Arthur Guy (C/S-S-J); Shepherd, Warren Ronald (C/S-S-J).
Brea — Pederson, John Alvin (C/S-S-J).
Glendale — Rosenquist, Edward Arthur, Jr. (C/S-S-J).
La Habra — Haseltine, Oran Lee (J).
La Jolla — Bostwick, Douglas Leland (C/S-S-J).
Long Beach — Moberg, Arthur Romayne, Sr. (M); Moberg, Arthur Romayne, Jr. (A); Whittaker, Horace Edgar (J).
Los Angeles — Comstock, Russell Irvin (C/S-S-J).
Menlo Park — Wishart, George Charles (M).
Taft — Brown, Harry Milford, Jr. (R,C/S-S-J); Jumah, Mahmud Naji (C/S-S-J).
Whittier — Larson, Valdemar Frick (R,C/S-S-J).

COLORADO

Denver — Richardson, Everett Ellsworth (M); Saye, Ed, III (C/S-J-M).

KANSAS

Lyons — Kenner, Robert James (C/S-S-J).
Wichita — Maxwell, Samuel Vinett (J).

LOUISIANA

Morgan City — Awezec, John Stephen (J).
New Orleans — Little, Sterling Edward (M); Martin, Henry Woods (J); Prell, Furness Martin (A).
Ruston — Jones, Jack (J).
Shreveport — Bell, Forrest William (M); Liscum, Frank Nelson (M); Thomas, Wyatt Hugh (J); Valerius, Claude Nathan (M); Walters, Jack Harding (M).

MASSACHUSETTS

Cambridge — Lovejoy, Donald Walker (J).

MISSISSIPPI

Waveland — Landers, Albert Frank (M).

NEW MEXICO

Hobbs — Rice, Douglas Wilson (C/S-S-J).

NEW YORK

Bronx — Brois, John Adam (C/S-S-J).

OKLAHOMA

Bartlesville — Clinton, George William (J); Drisko, Phillip Benny (C/S-S-J); Fisher, Henry Benedict (M); Murray, Robert Penhale (J).
Broken Arrow — Prentice, Robert George (J).
Dewey — Evans, Douglas Sanford (C/S-S-J).
Nowata — Turner, Neal Gene (C/S-S-J).
Oklahoma City — Swearingen, Wayne Elwyn (J).
Pauls Valley — Spell, Thomas Ross, Jr. (C/S-S-J).
Ponca City — Cook, Robert Edmond (C-S-S-J).
Stillwater — Shapiro, Robert Allen (C/S-S-J).
Tulsa — Bearden, William George (J); Beets, Raymond Wendell (A); Brock, Lawrence (M); Burge, Leonard Lee (M); Bush, John Burchard (M); Carr, Raymond Murray (M); Cecil, William Perry (M); Clarke, William R. (M); Collins, William Wesley (A); Cooper, James David (J); Einarsen, Charles Albert (J); Fast, Clarence Robert (M); Garst, Arthur Wilhelm (M); Grant, Bruce Fones (M); Harding, Richard Stanley (M); Healy, John Ehret (M); Lamoreaux, William Edward (M); Mallinger, Morton Arnold (J); O'Neill, Vernon Loran (M); Perry, Robert Oliver (M); Sage, John Franklin (M); Scott, Platho Phalos, Jr. (M); Skeith, Jack Theron (J); Smitherman, Eugene Alston (J); Stanton, Potter (M); Szasz, Stephen Emil (M); Walters, John DeWitt (J).

PENNSYLVANIA

State College — Hassen Mohey Eldin Mohamed Tawfie (J).

TEXAS

Abilene — Barthelemy, Weidon Frank (M); Clark, John Marshall (J); Cockrell, Robert B. (R,C/S-S-A); Eaton, John Roberson (J).
Alice — Austin, Ellis Harlton (J); Gallagher, Augustin C., Jr. (M).
Beeville — Barnes, Charles Walker (A); Henslee, William A. (M); Kundert, Alden Eugene (C/S-S-J).
Breckenridge — Ford, Thomas Arthur (M); Garbutt, George Henry (J).
College Station — Guerrero, Erasmo Trevino (J).
Corpus Christi — August, Alex David L. (M); Byrd, William Cullen (J); Fitzpatrick, Jack Cleo (J); Gardner, Howard E. (M); Jones, Jack Douglas (J); Miner, Robert Camp (M); Mott, James Denzil (A); Ray, Jack (A); Riley, Leo C. (M); Roberts, Alan Philip (J); Scibienski, Henry John (M); Slavik, Albert T. (A); Smith, Al Augustus (A); Smith, Hueland Forrest, Jr. (M); Stanley, Henry M. (A); Stiba, Benjamin Franklin (A); Story, Samuel August, Jr. (A); Terrill, Edd, Jr. (M); Vest, Harry Arthur (A); Waters, George Wilson (J).
Dallas — Erickson, Robert Arthur (J); Keating, Thomas James (C/S-S-J); LeRoy, Robert Clark (J); Moore, Jack Wesley (C/S-S-J); Swan, Charles Allan (C/S-S-J); Wahl, Jack (R,C/S-S-J).
Delmita — Shepherd, Jim Dale (C/S-S-J).
Falfurrias — Champion, Frank Baker, III (J); Luttrell, John George (C/S-S-J).
Fort Worth — James, Otis Lee, Jr. (C/S-S-J); Moffatt, Murray Carlton (R,C/S-J-M); Painter, Thomas Willits (M).
Houston — Beckelhymer, Roy Leonard, Jr. (C-S-S-J); Brown, Harry Winfield (C/S-J-M); McCullough, Thomas Bertrand (M); Mitchell, George Phydias (R,M); Sydow, Charles Henry, Jr. (M); Welsh, James Redmond (R,C-S-J-M).
Kilgore — St. Laurent, Charles Pierre (J); Sheffield, Neil Jackson (C/S-S-J).
Kingsville — Focht, Frank Tuck (J); Gibson, Charles Morrison (M); Wooddy, Lemuel Dale (J).
Lubbock — Livingston, Jennings Bryan (M).
McAllen — Tschirley, Norman Karl (A).
Midland — Childress, John Bowles (M); Collins, Alvah Edward (R,C/S-S-J); Downs, Stanford Lacy (J); Hayes, James C. (J); Howard, Joe R. (J); Lytle, William James, Jr. (M); Matthews, Thomas Alexander, II (J); Means, James Osborne (M); Moriarty, Kenneth Dean (C/S-S-J); Parsley, Joe Mac (R,J); Smith, Ray Perkins (J); Vicars, Rex Alvin (A); Wilkinson, Walter McCool (M).
Monroe City — McReynolds, James Harry, Jr. (M).
Odem — Drum, Wendell Raymond (M).
Odessa — Brown, Alfred D. (C/S-S-J); Gordon, Jack Finis (M); Hallford, John Duncan (J); Jones, Bobby Marcell (J); Winston, Harold Stanley (R,J).
Premont — Greene, Thomas James (R,C/S-S-J).
Sinton — Scott, James Corbett (A).

WASHINGTON

Seattle — Moon, John A. (C/S-S-J).

WEST VIRGINIA

Buffalo — Waggener, Charles Andrew (C/S-S-J).

THE NETHERLANDS

Amsterdam — Van Heiningen, Jan (M).

VENEZUELA

Caracas — Braun, Ernest Carl (J); Carter, Kenneth Hart (C/S-S-J); Rowley, Craig Morrison (M).
Lagunillas, Zulia — Gregston, Nolan Roger (J).
Maracaibo — Mauzy, Whit Yancey, Jr. (J); Stepanek, David Leslie (J). ★ ★ ★

HAVE YOU CHANGED YOUR ADDRESS?

In order that publications and correspondence may reach you promptly, the Petroleum Branch, AIME, should be advised as soon as possible of any change in your address, preferably a month before the change becomes effective. For the AIME directory and for the Personals column of the JOURNAL OF PETROLEUM TECHNOLOGY, additional information is desired. The form below is provided for your convenience, and should be sent to Petroleum Branch, AIME, 800 Fidelity Union Bldg., Dallas 1, Tex.

Name_____ Membership No._____

Old Address_____

New Address for Publications_____

Title or Position Held_____

Address for Directory Listing_____

List below your former title or company position, nature of your new position, or other information of interest to your associates for publication in the JOURNAL OF PETROLEUM TECHNOLOGY.

Visit the new offices of the Petroleum Branch, AIME, now located at 800 Fidelity Union Bldg., junction of Bryan, Pacific and Akard streets, Dallas, Tex.

San Ardo—Geologic Case History

Continued from Page 10, Section 1

accurate within a few feet, even when considerable and unexpected structural changes were encountered.

Gas cap study proved much easier than water study as it rapidly became evident that the gas-oil interface had readjusted to present structure forming a regular and level surface. The gas-oil interface (a three-ft gradational interval) was sharply defined by use of sidewall samples. Later it was picked from Microlog. (A heavier wall cake occurs opposite gas sand which is, of course, more permeable to water.)

With the completion of these studies, the early phase of San Ardo development was over. Then came a longer interval of field development. Outpost wells were gradually completed until (by late Spring of 1952) the limits of production were reasonably well defined. During this time it became evident that the entire San Ardo Field was a single accumulation and the various pool titles ("Aurignac," "Lombardi," and "Campbell") were gradually dropped. It became general knowledge, too, that the "King City" fault, which on the surface separates the field into two structural blocks, is a flat thrust fault which fades to the west out of the picture and does not affect the structure at depth.

Two principle productive sands are now recognized (Lombardi and Aurignac). The Aurignac sand, due to water table warping and gas-cap readjustment, presents the interesting case of a down-dip area in which oil-sand rests on granite and an up-dip area where gas rests on water.

Two stray sands (Orradre "24" and Orradre "28") of small size were located in Superior Oil Co. Orradre No. 1 where they were gray. It was predicted that they would be saturated at their local shale edge and later drilling found this anticipated additional reserve.

During this phase, wildcat exploration for other Salinas Valley fields of San Ardo type continued. Three new fields were found by Barnsdall-Cleveland Ansberry No. 1, Texas Co. Biaggi No. 2, and Jergins Oil Co. Aurignac No. 1, but each proved subcommercial.

At present, exploratory drilling in the area has appreciably slowed but the end is not yet — other important fields may still be uncovered by continued geologic effort of the type successful in the past. ★ ★ ★

San Ardo—Development History

Continued from Page 13, Section 1

the oil. It has been found by actual experience that approximately 1,200 bbl of oil produced in two days will fill a 1,600-bbl tank. One day is then required to complete the heating and defoaming. The tanks are then topped out with hot degassed oil from gauge tanks in the same battery. One day is then required for shipment. From this it is calculated that four bbl of storage are required per daily bbl of oil produced.

Each tank battery is equipped with a 200-bbl tank for test purposes. Gauging in 1,600-bbl tanks for test purposes is not satisfactory because of the time required to defoam the oil. The lead lines and tank facilities make it possible to test any well. Each well is tested once a month. All tanks are insulated.

Heating

All tank batteries are equipped with at least one 103 HP locomotive type boiler which supplies steam to tank coils at 15-lb pressure to degas the crude oil. These boilers are equipped with burners which fire on San Ardo crude oil or gas or both simultaneously. When crude is used for firing it must be preheated to 130°F to 150°F. All burners are equipped with automatic electric controls. Iron firemen, Ray and Petrol burners are used. Each 1,600-bbl tank is equipped with 300 ft of three-in. flat coils which is equivalent to 300 sq ft of surface. In addition, 1,200 ft of 1½-in. spiral coil is installed which is equivalent to 600 sq. ft. At the present time a vapor recovery system is being installed by one operator to gather gas for firing boilers. Some gas traps have been installed and operated successfully when heat is applied. This does not completely degas the oil, however.

During early development a minimum of gas was taken from gas cap wells. This was recognized as a bad practice since it dissipated reservoir energy which is critical in a low-gravity, high-viscosity type of reservoir such as San Ardo. Every effort is now being made to conserve gas.

Shipping

It has been found necessary to blend San Ardo crude with approximately 25 per cent cutter stock to facilitate shipping through long pipelines. Many tank batteries are equipped with 1,600 bbl of storage for cutter stock which is blended and delivered to the General Petroleum Corp. at 180°F. At pipeline station additional cutter stock is blended to give a gravity of from 14.0° to 14.8° API with a viscosity of 175 seconds furol at 180°F. The San Ardo pump station is equipped to move 30,000 B/D with a 500 HP steam pump operated at 400 psi pressure. Two additional pump stations are on the pipeline at Bradley and Adelaida. Thirty-nine miles of eight-in. crude line connects San Ardo with Estero Bay and a four-in. line is used to return cutter stock to San Ardo. At present the pipe line is capable of handling approximately 30,000 bbl of crude cutter stock blend per day. ★ ★ ★

Continuous Wildcat Well Logging

GEOLOGICAL WELL SERVICE COMPANY

(Geo-Service)

230 White Building

Abilene, Texas

Telephones: 2-9934, 2-8996

Experienced Geologists

in

On-location Laboratory Units

U.S.A. — Foreign

West Texas • New Mexico • Rocky Mountains

Williston Basin • Mid-Continent • Foreign

Call or wire collect for nearest field representative

Brochure and References on Request

Personals

GEORGE DECKER has been transferred from Wichita, Kans., to Midland, Tex., where he will be Permian Basin division manager for Schlumberger Well Surveying Corp. Decker was graduated from Missouri School of Mines in 1939. He joined Schlumberger in 1940 and has remained with the company except for three and one-half years in the United States Air Force from 1942-46.

+

MURRAY C. MOFFATT has been appointed manager of the Fort Worth division of Magnet Cove Barium Corp. Before his new appointment Moffatt was sales manager of the Fort Worth division. Before joining Magcobar in April, 1952, Moffatt was associated with the Gulf Oil Corp. in Fort Worth as a petroleum engineer. He received his degree in petroleum engineering from the University of Texas in 1941.

+

KEMP S. LEWIS has been appointed manager of mineral and chemical sales by the Baroid Sales Division, National Lead Co., at Houston, Tex. A chemical engineer and graduate of Rice Institute, Lewis joined Baroid as a service engineer in 1939. He served as district engineer in the well logging department from 1941 until entering the Navy in 1942. In 1945, he rejoined Baroid and was made a division superintendent in the well logging department in 1949.

+

ALEXANDER DEUSSEN, consulting geologist of Houston, Tex., and HARRY R. JOHNSON, consulting geologist of Los Angeles, Calif., have been elected to honorary membership in the American Association of Petroleum Geologists. Only 16 other living geologists have been so honored by the society. Deussen served as the second AAPG president in 1918-19, and was awarded the Sidney Powers Memorial Medal in 1947. He has long been a leader in geological exploration work on the Gulf Coast. Johnson served with the U. S. Geological Survey for several years after his graduation from Stanford University. His work has included the search for both petroleum and municipal water supplies, especially on the West Coast.

+

W. W. LEONARD has been appointed assistant manager of tubular sales for The Colorado Fuel and Iron Corp., according to an announcement by R. E. Metzger, manager of tubular sales. Leonard's appointment is in preparation for the marketing and servicing of products from the company's new seamless pipe mill scheduled to open in the fall of 1953. Leonard is a native of Texas and a Texas College of Mines and Metallurgy graduate engineer. His pipe experience began with Youngstown in 1936 as a metallurgist in seamless and E/W pipe. In 1939 he was transferred to Shreveport as a field engineer on tubular products. In 1944 he was transferred to the Continental Supply Co. on sales of tubular products in Louisiana, Arkansas, Mississippi and East Texas. For the past few years he has been district manager of tubular sales for Continental Supply Co.

R. J. S. PIGOTT, director of engineering, Gulf Research and Development Co., was to retire from that position on Jan. 1. He will, however, continue in the capacity of consultant. He was graduated from Columbia University in 1906 with a degree in mechanical engineering. He holds more than 30 patents on devices used in hydraulic engineering, heating, oil production, and instruments, and is the author of more than 40 technical papers. Pigott has just completed his term as president of the American Society of Mechanical Engineers. He was president of the Instrument Society of America in 1950, and is a past president of the Society of Automotive Engineers (1948)—the first oil man to hold this office. He has also served as president of the American Society for Measurement and Control.

+

EDWARD H. JUDSON has become a partner in the firm of Martin, Williams and Judson, petroleum consultants in Midland, Tex., with offices in the Central Bldg. He was formerly exploitation engineer for the Shell Oil Co. in Houston.

+

R. E. WAINERDI has been recalled to active duty as lieutenant in the United States Air Force Reserve. He had been employed as a junior petroleum engineer with the Shell Oil Co. in Houston, Tex.

+

DALTON MOORE, JR., has been named manager for the Wimberly Field and Wimberly Flippen Sand Units, located near Abilene, Tex. He is a 1940 graduate of Texas A&M College, with a degree in petroleum and mechanical engineering. Previously, he has worked with Gulf Oil Corp. in East Texas and with The Chicago Corp. at Corpus Christi. Recently, he was superintendent for Burdell Oil Co. in Snyder, Tex. Moore is vice-chairman of the West Central Texas Section of AIME.

ADVANCE AIME MEETING CALENDAR

	1953	1954
AIME Annual Meeting	Feb. 15-19 Statler Hotel Los Angeles	Feb. 14-18 Statler Hotel New York
AIME Fall Meeting	El Paso	
Petroleum Branch Fall Meeting (Mid-Continent)	Oct. 18-21 Baker and Adolphus Hotels, Dallas	San Antonio, Tex.
Regional Meeting, Pacific Petroleum Chapter	Oct. 1-2 Ambassador Hotel Los Angeles	Not determined

General Income to Cover Metals Branch Deficit

More time was given by the Board at its Nov. 19 meeting to the matter of financing the Metals Branch deficits than to any other subject. Walter A. Dean presented a report of the Committee to Study Sustaining Memberships for the Metals Branch, of which he was chairman. A total of 1,000 pages of Metals Branch Transactions in 1953 was though desirable, 750 pages for IMD, and the balance for EMD and ISD. A part of this material would be issued as supplements to the JOURNAL OF METALS. If this amount of Transactions material were published, a deficit of $20,000 to $25,000 could be expected in the Metals Branch in 1953. To meet this deficit, contributions of from $200 to $500 would be solicited from industrial concerns, institutional groups, and individuals interested in supporting publication of this type of material. After long discussion the directors voted nine to seven against adoption of the proposed plan for contributions at this time. Instead, the Board took the position that for the coming year the deficit to be incurred by the proposed publishing plan should be met out of the general income of the Institute, as it has in the past. The matter is to be reconsidered if it later appears advisable to do so. ★ ★ ★

AIME - Socony-Vacuum Scholarship Awarded

James E. Cockfield has been awarded the AIME - Socony-Vacuum Scholarship in the amount of $750, it has been announced by Harry H. Power, chairman of the Mineral Industry Education Division.

Cockfield will receive the Bachelor and Master degrees from Ohio State University in June. His point-hour ratio is 3.77 and he stands fifth in a class of 257. Presently he is working on his thesis which deals with the effects of temperature, pressure, and permeability on gravity drainage in oil reservoirs.

Cockfield is vice-president of the AIME student Chapter at Ohio State and is also active in Tau Beta Pi, Sigma Gamma Epsilon, Phi Eta Sigma and other campus organizations. Recently he was given the Tarr Award, a certificate given annually by each chapter of Sigma Gamma Epsilon (earth sciences honorary fraternity) for a student's achievements in the earth sciences.

Cockfield's transcript includes 49 "A's," 16 "B's," and two "C's." ★ ★ ★

. . . who's got the button?

you have!

Our customers also deserve an Otis service pin. As we approach our silver anniversary year we gratefully acknowledge *your* share in our progress . . . in making Otis the only organization in the Industry with a full complement of "pressure control" facilities — from manufacturing and marketing to field service crews which offer a large variety of services conducted "under pressure." Thank you for your part — for being our customers.

PRESSURE CONTROL OTIS SERVICE - EQUIPMENT

Otis Pressure Control, Inc.

Established in 1928 by H. C. Otis as The Southern States Company

Quick-Freezing vs Saturation of Cores

Continued from Page 22, Section 1

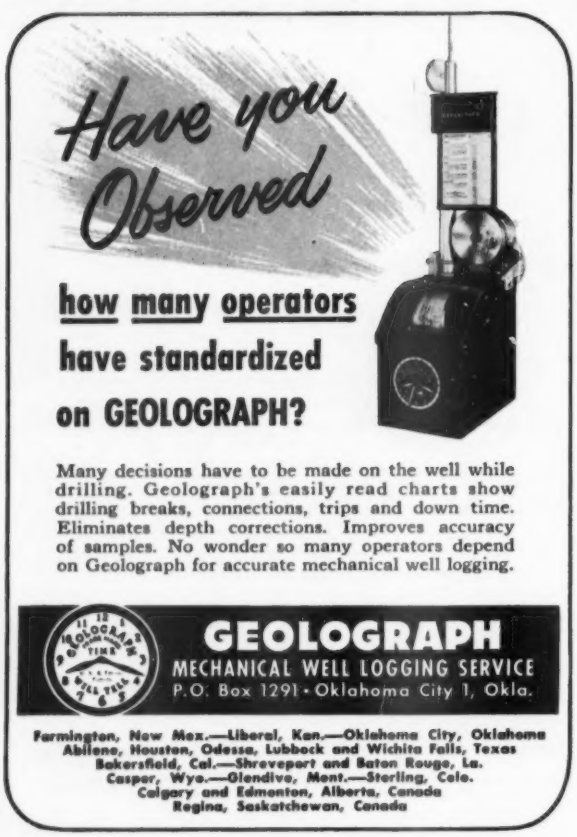
compared with corresponding data on adjacent samples not frozen. These results combined with similar data obtained by Wisenbaker[3] in a prior investigation showed an overall average increase due to quick-freezing of 2.7 per cent in permeability and 2.5 per cent in porosity, for 177 pairs of samples. Changes in fluid saturations were small. It is concluded that for all practical purposes any changes in permeability, porosity and fluid saturations of oil well cores brought about by quick freezing are negligible.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Robert F. Knight, George Maly and Kathleen Rencz of Core Laboratories, Inc., for their assistance in carrying out the laboratory work presented here, and to the others who have contributed to the data.

REFERENCES

1. Lewelling, H., and Grubb, W. E.: "Variables Affecting Restored-State Determination of In-Place Oil," Presented at Fall Meeting of Petroleum Branch, AIME, Houston, Tex., Oct. 1-3, 1952.
2. Lebeaux, J. M.: "Some Effects of Quick-Freezing Upon the Permeability and Porosity of Oil Well Cores," *Jour. Pet. Tech.*, (Nov., 1952), 4, (11), 19.
3. Wisenbaker, J. D.: "Quick Freezing Seals Fluid Content in Cores," *Oil and Gas Jour.*, (Jan. 25, 1947), 275. ★★★


Have you Observed
how many operators
have standardized
on GEOLOGRAPH?
Many decisions have to be made on the well while drilling. Geograph's easily read charts show drilling breaks, connections, trips and down time. Eliminates depth corrections. Improves accuracy of samples. No wonder so many operators depend on Geograph for accurate mechanical well logging.
GEOLOGRAPH
MECHANICAL WELL LOGGING SERVICE
P.O. Box 1291 • Oklahoma City 1, Okla.
Farmington, New Mex.—Liberal, Kan.—Oklahoma City, Oklahoma
Abilene, Houston, Odessa, Lubbock and Wichita Falls, Texas
Bakersfield, Cal.—Shreveport and Baton Rouge, La.
Casper, Wyo.—Glendive, Mont.—Sterling, Colo.
Calgary and Edmonton, Alberta, Canada
Regina, Saskatchewan, Canada

Advertisers' Index

A-1 Bit and Tool Co. . . . . *
Clausel Industrial Advertising, Houston
B and W Incorporated . . . . . Sec. 1—5
Brennan Advertising Agency, Houston
Baash-Ross Tool Co. . . . . Sec. 1—28
Dozier-Eastman & Co. Los Angeles
Baker Oil Tools, Inc. . . . . Sec. 1—6, 7
Theo. M. Martin Co., San Gabriel, Calif.
Baroid Sales Division . . . . . *
Darwin H. Clark Co., Los Angeles
Barret, William M., Inc. . . . . *
Bozell & Jacobs, Inc., Shreveport
Clark Bros. Co., Inc. . . . . *
Harold Warner Co., Buffalo. N. Y.
Cooper-Bessemer Corp. . . . . Sec. 1—16
Griswold-Eshleman Co., Cleveland
Core Laboratories, Inc. . . . . *
Duvall Williams, Dallas
Dowell Incorporated . . . . . Sec. 1—8
MacManus, John & Adams, Inc., Detroit
Dresser Industries, Inc. . . . . *
Laughlin, Wilson, Baxter & Persons, Dallas
Eastman Oil Well Survey Co. . . . . *
Ted Workman Advertising, Dallas
Geograph Co., Inc. . . . . Sec. 2—8
Lowe Runkle Co., Oklahoma City
Geological Well Service Co. . . . . Sec. 2—5
Halliburton Oil Well Cementing Co. . . . Sec. 1—1, 27
Hill & Christopher, Los Angeles
Hughes Tool Co. . . . . Third Cover
Foote, Cone & Belding, Houston
Hycalog Co. . . . . Sec. 1—20
Glenn Mason Advertising, Shreveport
Infilco, Inc. . . . . *
Ruthrauff & Ryan, Inc., Hollywood, Calif.
International Petroleum Exposition . . . . . *
Gibbons Advertising Agency, Inc., Tulsa
Johnston Testers, Inc. . . . . Sec. 1—23
Wallace Davis & Co., Houston
Keystone Development Corp. . . . . *
Brennan Advertising Agency, Houston
Kobe, Inc. . . . . *
The McCarty Co., Los Angeles
Lane-Wells Co. . . . . Fourth Cover
Darwin H. Clark Co., Los Angeles
Lufkin Foundry & Machine Co. . . . . Sec. 1—4
A. E. Cudlipp, Lufkin, Texas
Magnet Cove Barium Corp. . . . . *
Rives, Dyke & Co., Houston
McCullough Tool Co. . . . . Sec. 1—2
R. P. Casterline, Los Angeles
Moore, Lee C., Corp. . . . . *
Watts, Payne Advertising, Tulsa
Oil Base, Inc. . . . . *
Dozier,Eastman & Co., Los Angeles
Otis Pressure Control, Inc. . . . . Sec. 2—7
Dan Goodrich, Dallas
Pelton Water Wheel Co. . . . . Sec. 1—15
Edward A. Stratman, Huntington Park, Calif.
Professional Services . . . . . Sec. 1—24
Schlumberger Well Surveying Corp. . . . Second Cover
Rives, Dyke & Co., Houston
Second National Bank of Houston . . . . . *
Gano, Bachrodt, Edwards, Inc., Houston
Sperry-Sun Well Surveying Co. . . . . *
Wallace Davis & Co., Houston
United Geophysical Co., Inc. . . . . *
Dozier, Eastman and Co., Los Angeles
Welex Jet Services, Inc. . . . . *
Evans & Associates, Fort Worth
Well Surveys, Inc. . . . . *
Watts, Payne Advertising, Tulsa
Western Geophysical Co. . . . . *
L. J. Swain Advertising, Whittier, Calif.
Zublin Flexible Drill Pipe . . . . . *
Roy F. Irvin Advertising, Los Angeles
*In Previous Issues

Testing velocity and jetting characteristics of nozzles of jet rock bit in Hughes Research and Engineering Laboratory.

Getting the most out of your jet bits ?

To get the maximum potential performance out of your jet bits it is necessary to be acquainted with the hydraulics involved.

A continuing study of jet bit drilling by Hughes engineers has resulted in the preparation of a new booklet—"Hydraulics for Jet Bits." This practical booklet sets forth operating data in tabular form for ready reference. It also contains information that will help you determine the hydraulic requirements for running jet bits, and how to efficiently utilize the hydraulic capacity of your equipment.

When you run a HUGHES jet bit you know that it is backed by thorough research and an experience of 43 years in building the industry's best bits.

"Hydraulics for Jet Bits"— a valuable new Hughes booklet available through your local Hughes representative.

all for the price of one

When you buy shaped-charge perforating, you're ordering "deep penetration." But Lane-Wells KONESHOT gives you more than that — it gives you the all-important extras of *accurate depth measurement* to put the shots where you want them; unequalled *safety* for well and crew; *experience* gained in 175,000 perforating jobs; *service* from 71 branches, and *speed* on the job. And *all* these extras come with every KONESHOT job... why settle for less?

AK-509

KONESHOT
is the "plus-value" shaped-charge perforating

LANE WELLS

General Offices, Export Office, Plant • 5610 So. Soto St., Los Angeles 58

LOS ANGELES • HOUSTON • OKLAHOMA CITY • LANE-WELLS CANADIAN CO. IN CANADA • PETRO-TECH SERVICE CO. IN VENEZUELA